THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

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BRITISH STANDARD 'EMERGENCY' CASE-HARDENING STEELS

BRIT. STANDARDS INSTN.: 'Emergency Specifications for Case-Hardening Steels. *Addendum No.* 1: Nov. 1951 to B.S. 970: 1947 (see also *Metallurgia*, 1951, vol. 44, Dec., p. 311; and *Machinist*, 1951, vol. 95, Dec. 22, pp. 1956-7).

As a result of the present serious shortages of alloying elements for steel, the Ministry of Supply has set up a Steel (Rearmament) Panel, under the Chairmanship of Mr. E. Senior. This Panel has established a Technical Committee, of which Mr. H. H. Burton is Chairman. The Technical Committee has under consideration the problem of economy in the use of alloying elements, by replacing specifications in which their content is relatively high, by others stipulating much lower alloy contents.

Following the initial deliberations of the Committee, the British Standards Institution has issued a series of emergency specifications for case-hardening steels, which are intended, as an emergency measure, to replace the standard alloy case-hardening types covered by B.S. 970: 1947, i.e., En 33, 34, 35, 36, 37, 38, 39 and 325.

Particulars of the emergency alternative steels are given in Tables I and II, in which the data have been derived from the British Standards and presented in such a manner as to facilitate easy reference. It will be noted that two groups, En 351-353 and En 361-363, have been adopted, to cater for possible differences in the availability of alloy-steel scrap at different works.

Table I

New Emergency Case-Hardening Steels

Addendum No. 1—Nov., 1951, to B.S. 970: 1947

En No.	Type	Chemical Composition					Mechanical Properties of Core			
							Max. Stress		Elongation	Izod Impact
		C %	Mn %	Ni %	Cr %	Mo %	t.s.i. min.	kg./mm.^{2} min.	% min.	ft.-lb. min.
351	¾% Ni-Cr	0·20 max.	0·60-1·00	0·60-1·00	0·40-0·80	0·10 max.	45	71	18	30
352	1% Ni-Cr	0·22 max.	0·50-1·00	0·85-1·25	0·60-1·00	0·10 max.	55	86	15	20
353	1¼% Ni-Cr	0·22 max.	0·50-1·00	1·00-1·50	0·75-1·25	0·08-0·15	65	102	12	20
354	1¾% Ni-Cr	0·22 max.	0·50-1·00	1·50-2·00	0·75-1·25	0·10-0·20	75	118	12	20
355	2% Ni-Cr-Mo (lower Cr)	0·20 max.	0·40-0·70	1·30-2·20	1·40-1·80	0·15-0·25	85	134	12	25
361	'15' Carbon low-alloy	0·13-0·17	0·70-1·00	0·40-0·70	0·55-0·80	0·08-0·15	45	71	18	25
362	'20' „ „ „	0·18-0·23	0·70-1·00	0·40-0·70	0·55-0·80	0·08-0·15	55	86	15	15
363	'25' „ „ „	0·22-0·26	0·70-1·00	0·40-0·70	0·55-0·80	0·08-0·15	65*	102	—	—

* Required only if steel is supplied on the basis of tensile strength.

Note 1. Heat-treatment of the test bar consists of:—
(*a*) Blank carburize at 880°-930°C. (*b*) Refine at 850°-880°C.
(*c*) Harden in oil from 780°-820°C. (*d*) Temper at not more than 200°C.: for En 355 only.

Note 2. The test bars are of 1½-in. diam. (28·6 mm.) except in the case of En 355, when the test bar is machined to test-piece size (except for a grinding allowance, if required) prior to heat-treatment.

Note 3. In all steels the silicon content is 0·35 max. per cent., and the sulphur and phosphorus are each 0·05 max. per cent.

Attention may also be drawn to the appearance of a new tensile range which has no equivalent in the standard series; this is En 354, which relates to a steel having a minimum tensile strength of 75 tons per square inch. The steel covered by En 355 is intended to replace En 320, which was issued towards the end of the last war as an alternative to En 39. Experience with En 320 has shown that this steel is prone to formation of carbide networks in the carburized case, and it has never seriously competed with En 39A and B, the 4½ per cent. nickel-chromium and nickel-chromium-molybdenum steels. It is hoped that the modified composition covered by En 355 may to some extent obviate this defect.

Table II

Alternative 'Standard' and 'Emergency' Case-Hardening Steels Related to Mechanical Properties

Mechanical Properties			'Standard' Steels B.S. 970: 1947		'Emergency' Steels Addendum No. 1 to B.S. 970: 1947	
Tensile Strength		Izod Impact ft.-lb. min.	En No.	Type	En No.	Type
t.s.i.	kg./mm.²					
40-60	63-94	50	37	5% Ni		
45 min.	71	40	33	3% Ni		
,,	,,	,,	34	2% Ni-Mo (lower C)		
,,	,,	30			351	¾% Ni-Cr
,,	,,	25			361	'15' Carbon low-alloy
55-75	86-118	35	36T	3% Ni-Cr		
55 min.	86	,,	325	Low Ni-Cr-Mo		
,,	,,	25	35	2% Ni-Mo (higher C)		
,,	,,	20			352	1% Ni-Cr
,,	,,	15			362	'20' Carbon low-alloy
65-80	102-126	30	36V	3% Ni-Cr		
65 min.	102	,,	38	5% Ni		
,,	,,	20			353	1¼% Ni-Cr
,,	,,	—			363	'25' Carbon low-alloy
75 min.	118	20			354	1¾% Ni-Cr
85 min.	134	25	39A	4¼% Ni-Cr		
,,	,,	,,	39B	4¼% Ni-Cr-Mo		
,,	,,	,,	320	2% Ni-Cr-Mo		
,,	,,	,,			355	2% Ni-Cr-Mo (low Cr)

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Correlation of Test Data with Service Performance

AMER. SOC. METALS: 'Interpretation of Tests and Correlation with Service.' Series of Four Educational Lectures, presented during National Metals Congress, 1950.
Published by the Society, 1951; 198 pp.

The four papers contain descriptions of the nature of the tests currently used for determination of the mechanical, physical and corrosion-resisting properties of metallic materials, and critical discussions of the extent to which the data obtained by the respective tests can be used as a reliable criterion of service performance. The discussions are illustrated by typical test results on various materials, including ferrous and non-ferrous types in which nickel is an integral constituent.

M. F. GARWOOD and H. H. ZURBURG: 'Correlation of Laboratory Tests and Service Performance,' pp. 1-77.
M. GENSAMER: 'Limitations of Mechanical Testing,' pp. 78-87.
J. T. BURWELL: 'Wear Tests and Service Performance,' pp. 88-140.
F. L. LAQUE: 'Corrosion Tests and Service Performance,' pp. 141-92.

Each of the papers is supported by a useful *bibliography*.

Electron Tubes: Textbook

W. H. KOHL: 'Materials Technology for Electron Tubes.' *Published by Reinhold Corpn.*, 1951; 493 pp. Price 10 dollars.

The declared purpose of this book is 'to present the physical characteristics of the solids used in the fabrication of vacuum tubes and to describe some of the processes for the application of these materials.' The aim is to meet the needs of the tube designer, development engineer and technician alike, giving up-to-date information broadly comparable in scope with that contained in the classic treatise by ESPE and KNOLL, 'Werkstoffkunde der Hochvakuumtechnik', published in 1936.

It is of interest to note that, in view of the wide range of specialist subjects calling for treatment in such a book, the author has submitted the chapters to individual experts in the respective branches: a list of reviewers of the text is given at the beginning of the book. The presentation may therefore be considered to be the concerted effort of many specialists, correlated into a whole which should be of value to a wide public. The *scope* of the information presented is indicated by the contents list, given below. Attention is directed to the intentional omission of full treatment of certain subjects which might be expected to form part of such a book, e.g., luminescence of solids, treatment of gases and vapours, electron emission, and high-vacuum technique. The author considers that these subjects have recently been dealt with adequately in specialized publications which are readily accessible to those interested.

Chapters

1. Physics of Glass.
2. The Annealing of Glass.
3. Strain Analysis of Glass.
4. Glass-to-Metal Seals.
5. Electrical Conduction in Glass.
6. Glass in Radiation Fields.
7. Electrons, Atoms, Crystals and Solids.
8. Tungsten.
9. Molybdenum.
10. Tantalum.
11. Nickel.
12. Copper.
13. Carbon and Graphite.
14. Joining Metals by Soldering and Brazing.
15. Ceramics and Mica.
16. Ceramic-to-Metal Seals.
17. The Phase Rule.
18. High-Vacuum Technique.
19. Thermionic Emission.

Extensive *bibliographies* are given at the end of each chapter. There are good subject and author indices.

Hardness Testing at Elevated Temperatures: Hot-Hardness of Electrodeposited Nickel

A. BRENNER: 'Microhardness Tester for Metals at Elevated Temperatures.' *Jnl. Research, Nat. Bur. Standards*, 1951, vol. 46, Feb., pp. 126-31; R.P. 2185.

The difficulties inherent in hardness-testing of thin deposits, especially at elevated temperature, are considered, and the limitations of instruments used for testing of bulk metals are indicated. A detailed description is then given, with good illustrations, of apparatus developed at the National Bureau of Standards, for microhardness determinations on coatings. The test is suitable for making measurements at temperatures up to 900°C., in an inert atmosphere, on coatings thicker than about 0·07 mm. (0·003 in.). The main parts of the equipment are: (1) the indenting mechanism, consisting of a Vickers diamond mounted on a shaft of fused silica; (2) a mechanical device for raising and lowering the indenter; (3) a micrometer device for orienting the specimen under the indenter; and (4) the heating unit. The force on the indenter is varied either by dead-weight loading or by changing the gas pressure inside the apparatus.

Typical data obtained by the use of the new instrument are presented. These include hot-hardness values for soft and hard chromium, nickel (deposited from an all-chloride bath), and copper; cobalt-tungsten alloys; molybdenum; cobalt, and cobalt-phosphorus alloys. In all cases values are shown at intervals over the range room temperature to 800°C., and the hardness of the respective materials at room temperature, after cooling from 800°C., is also given. It is noted that nickel and chromium are permanently softened by heating to this temperature, whereas cobalt and cobalt alloys regain a large proportion of their initial hardness on cooling and may even increase in hardness, provided that the maximum temperature of heating has not been excessive. It is emphasized that the figures shown are given solely to illustrate the use of the new instrument, and not as part of a systematic investigation of the hot-hardness of the electrodeposits tested.

NICKEL

Atomic Heat of Nickel

O. KUBASCHEWSKI: 'The Atomic Heats of Some Metals.' *Zeitsch. für Metallkunde*, 1950, vol. 41, Dec., pp. 445-51.

Critical review of existing data, including reference to values obtained by the author and his colleagues, correlated with data published by other investigators. On the basis of all the values reported, a tabular summary is made of melting points and heats of fusion for 35 elements, including nickel.

Nickel-Amalgams: Pyrophoric Nickel Powders

See abstract on p. 8.

Frictional Properties of Nickel

F. P. BOWDEN and J. E. YOUNG: 'Friction of Clean Metals and the Influence of Adsorbed Films.' *Proc. Royal Soc., Ser. A.*, 1951, vol. 208, Sept. 7, pp. 311-25.

The paper reports an experimental study of the friction behaviour of thoroughly degassed metal surfaces. The metals used, each sliding on itself, were nickel, iron, platinum and uranium. Apparatus is described in which it is possible to measure friction at any desired temperature up to 1200°C. or above, in vacuo, or in a selected gas.

The results show that when sufficiently-cleaned metals are allowed to touch, even at room temperature, complete seizure occurs. Over the real area of contact the specimens adhere with the bulk strength of the metal, and this area increases greatly with continued or attempted sliding.

The influence of surface layers of hydrogen, oxygen, water vapour, fatty acids, hydrogen sulphide, and chlorine, on friction, was also determined. It was found that these contaminants are most effective lubricants in cases in which they can react with the metal to form a solid and chemically attached film which is several molecular layers in thickness. The results demonstrate that the frictional behaviour of metals is very largely governed by the nature of the surface films formed, and by the extent to which they reduce the amount of metallic contact between the surfaces. The fact that metal surfaces are always to some extent contaminated prevents the complete seizure which would otherwise occur and render sliding impossible.

Magnetic Characteristics of Thin Nickel Films

A. DRIGO: 'Spontaneous Magnetization and the Curie Point of Very Thin Ferromagnetic Films.' *Nuovo Cimento*, 1951, vol. 8, pp. 498-501.

A preliminary report on measurements made on films of iron, cobalt and nickel, ranging in thickness from 6000 to 10 at. layers. It was observed that as the thickness decreased the saturation magnetization at 16°C. also decreased and the Curie temperature fell.

Nickel-Sulphide Catalysts: Reference Data

W. J. KIRKPATRICK: 'Nickel Sulfide Catalysts.' Contained in *Advances in Catalysis*, 1951, vol. 2, pp.329-39.

One of a series of well-documented reviews of recent developments.

Nickel Subsulphide Catalysts in Removal of Sulphur from Gas

INDUSTRIAL GAS DEVELOPMENT COMMITTEE: 'The Catalytic Removal of Sulphur from Town Gas.' *I.G.D.C. Publn.* 51/1/81: *D.*072, 1951; 3 pp.

The report is a sequel to I.G.C.C. Report No. 41/4/59, D.072, entitled 'The Production of Low Sulphur Content Atmospheres for Heat-Treatment Processes. Since the publication of the earlier report further experience has been gained, in the light of which the plant described in it has been re-designed, without alteration of principle. As before, the plant makes use of the nickel catalyst developed in the laboratories of the Gas, Light and Coke Company, of which the active material is nickel subsulphide, Ni_3S_2, on small cylindrical supporting pieces of porous, fired, china clay. The catalytic process, described in the present report, is covered by British Patents 489,398 and 529,711, and a special iron-oxide purification method incorporated in it is the subject of British Patent 567,231.

The report discusses the application of the process to removal of sulphur from gas for furnace atmospheres and gives a short illustrated description of standard sulphur-removal plant suitable for industrial consumers.

Desulphurization by Raney Nickel Catalyst

C. D. HURD and B. RUDNER: 'Raney Nickel Desulfuration.' *Jnl. Amer. Chemical Soc.*, 1951, vol. 73, Nov., pp. 5157-60.

The authors report work with Raney nickel prepared by three different procedures: (1) a method described

by MOZINGO (*ibid.*, 1943, vol. 66, p. 1015); (2) a procedure somewhat similar to that used for the Adkins-Pavlic W-4 nickel (*ibid.*, 1947, vol. 69, p. 3039); and (3) a method similar to that used by RALLS, DODSON and RIEGEL (*ibid.*, 1949, vol. 71, p. 3320). The hydrogenolytic activity of the resulting nickels increased in the order 1, 2, 3. No. 3 catalyst appeared to contain a much greater amount of adsorbed hydrogen than the other two.

The activity of these catalysts was investigated in the desulphurization of three compounds containing the thiocarbonyl group, five thiazoles, and one thiophene derivative. From *o*-tolyl isothiocyanate or *o*-tolylthiourea the product obtained was *o*-toluidine. Thiobenzanilide gave rise to *N*-benzylaniline. Aniline was the major product from 2-mercaptobenzothiazole, with lesser quantities of *o*-aminothiophenol and benzothiazole. Acetophenone was formed in quantity from both 2-mercapto- and 2-amino-4-phenylthiazole: other products from the latter were methylamine and 1-phenylethylamine, and from the former 4-phenylthiazole. Acetamide and acetaldehyde were the chief products, respectively, from 2-amino- and 2-mercapto-4-hydroxythiazole. 2-Thienyl methyl ketone underwent desulphurization into 2-hexanone, but small quantities of acetaldehyde and ethyl alcohol were also formed.

Reactions of Carbon Monoxide and Hydrogen with Nickel Catalyst during Synthesis of Gasoline

I. A. ZAIDENMAN and K. G. KHOMYAKOV: 'The Initial Stages of the Interaction of Carbon Monoxide and Hydrogen with the Nickel Catalyst at the Temperatures of Synthesis of Gasoline.' *Doklady Akad. Nauk S.S.S.R.*, 1951, vol. 78, pp. 901-4.

A detailed abstract appears in *Chemical Abstracts*, 1951, vol. 45, p. 8336. The catalyst studied was of the Raney type.

Nickel and Nickel-Cobalt Catalysts for the Fischer-Tropsch Synthesis

S. WATANABE (revised and edited by R. C. GRASS): 'Bench-Scale Studies of the Fischer-Tropsch Synthesis over Iron, Nickel and Nickel-Cobalt Catalysts (Japan).' *U.S. Dept. of the Interior, Bur. Mines Information Circular* 7611, June, 1951; 26 pp.

Deficiency in petroleum resources led the Japanese Government to carry out, as a war effort, much research on production of liquid fuels by synthesis; figures are given in this report for 1944, when the Japanese output reached its maximum.

The information recorded on nickel and nickel-cobalt catalysts shows that maximum yields of oil obtained in bench-scale equipment were as follows:—

Using 100 Ni: 20 Mn: 100 kaolin: 200 diatomaceous-earth catalyst, a maximum yield of 133·8 cm.^{3}/m^3 of pure $CO+2H_2$ was obtained from one pass of the feed gas. With a nickel-cobalt mixed catalyst (Ni:Co =3:7), having the composition 100 (Ni+Co): 8 MgO: 5 ThO_2: 200 diatomaceous earth a maximum of 172·2 cm.^{3}/m^3 of pure $CO+2H_2$ was obtained.

Volumetric Determination of Nickel

V. S. SYROKOMSKII and S. M. GUBEL'BANK: 'New Volumetric Method for Determining Nickel.' *Zhur. Anal. Khim.*, 1951, vol. 6, pp. 207-10: *Chemical Abstracts*, 1951, vol. 45, p. 8398.

Nickel dimethylglyoxime, twice precipitated, is dissolved in 7-*N* H_2SO_4, the organic radical is oxidized with 0·02-*N* $V_2O_3(SO_4)_2$, and the excess is titrated with standard $FeSO_4$ solution. The authors state that the method has been used in estimation of nickel in the presence of copper.

Heptoxime as Reagent for Determination of Nickel

R. C. FERGUSON, R. C. VOTER and C. V. BANKS: '1, 2-Cycloheptanedionedioxime as a Microgravimetric Reagent for Nickel.' *Mikrochemie ver. Mikrochimica Acta*, 1951, vol. 38, pp. 11-14.

By means of 1, 2-cycloheptanedionedioxime (heptoxime), yellow Ni $(C_7H_{11}N_2O_2)_2$ can be quantitatively precipitated at pH 2·7 or above. It can be weighed after drying at 110°-120°C. The degree of accuracy which can be obtained is demonstrated by typical analytical examples.

Spectrophotometric Determination of Nickel using Heptoxime

R. C. FERGUSON and C. V. BANKS: 'Spectrophotometric Determination of Nickel using 1, 2-Cycloheptanedionedioxime.' *Analytical Chemistry*, 1951, vol. 23, Oct., pp. 1486-7.

1, 2-cycloheptanedionedioxime (heptoxime) has been found to be a very satisfactory analytical reagent for both macro- and micro-gravimetric determination of nickel (*ibid.*, 1949, vol. 21, p. 1320). See also previous abstract.

The present note reports a study of the reaction of the same reagent with nickel in presence of oxidizing agents in strongly basic solutions. The results indicate that although heptoxime appears to have no particular advantage over dimethylglyoxime or nioxime with respect to stability of the colour produced, it provides a more sensitive method for the spectrophotometric determination of nickel. Full details of recommended procedure are given.

Electron Tubes: Textbook

See abstract on p. 4.

Influence of Magnetic Field on Elastic Properties of Nickel

R. M. BOZORTH: 'Frequency Dependence of Elastic Constants and Losses in Nickel.' *Bell System Tech. Jnl.*, 1951, vol. 30, Oct., pp. 970-89.

The investigation reported in this paper was made on single crystals of nickel grown by slow cooling of the melt in a molybdenum-wound resistance furnace, by a method described earlier by the author and others (*Rev. Scientific Instruments*, 1949, vol. 20, p. 947).

The elastic constants of the crystals, and their variation with magnetic field (ΔE effect), were measured by a 10-megacycle ultrasonic pulsing method. The constants of three crystals were found to agree well with one another when the crystals were magnetically saturated, but they varied with domain distribution when demagnetized. The maximum ΔE effect observed (3 per cent.) was much less than has been observed at lower frequencies (20 per cent.). By measuring the ΔE effect and the decrement of polycrystalline rods at low frequencies, it is shown that the small effect found at 10 megacycles is due to a relaxation in the domain-wall motion due to micro-eddy-current damping.

From the initial slope of the decrement-frequency curve, and also from the frequency of maximum decrement, the size of the average domain is found to be about 0·04 mm. A photograph of actual domains in single crystals of nickel, observed optically by Williams, is reproduced in the paper. The average domain size derived from the authors' experiments is somewhat larger than that previously obtained in 68 Permalloy, a result which would be expected, since nickel has a very high magnetostriction, and the movement of domain boundaries by stress will be relatively large, possibly so large that the regions swept over by the domain walls will correspond to whole domains of the original domain structure, when stresses are equal to those used in the experiment reported. The domain size determined by the authors is based on this interpretation.

Effect of Magnetic Field on Acoustical Properties of Nickel and Nickel-Iron Alloys

J. DE KLERK: 'Effect of a Magnetic Field on the Propagation of Sound Waves in a Ferromagnetic Material.' *Nature*, 1951, vol. 168, Dec. 1, pp. 963-4.

Experiments on the propagation of high-frequency longitudinal acoustic waves along a rod of ferromagnetic material have shown such waves to be influenced in two ways by the application of an external magnetic field. The velocity of propagation is modified, as would be anticipated from the ΔE effect in magnetostriction experiments, and the attenuation of the waves is, in general, reduced as the applied field is increased, confirming observations made by other investigators.

The present note refers to experiments with both transverse and longitudinal magnetic fields. In both cases a decrease of attenuation was observed as the magnetization approached saturation. Equipment with which the measurements were made is described, and data are recorded relating to experiments with nickel and a nickel-iron alloy of unspecified composition.

Inert-Arc Welding of Nickel, Nickel-Alloy and Stainless-Steel Tubing

R. S. ZENO and H. L. C. LESLIE: 'The Inert-Arc Welding of Thin-Walled Tubing.' *Welding Jnl.*, 1951, vol. 30, Nov., pp. 986-92.

The paper reports work done by the General Electric Company (in their Knolls Atomic Power Laboratory) primarily to determine the factors influencing inert-arc welding of thin-walled tubing of Type 347 stainless steel, 'A' and 'L' nickels, S.A.E. 1020 carbon steel, ductile titanium, molybdenum, and Fernico (nickel-cobalt-iron alloy). In the case of Fernico conditions for joining it to nickel and stainless steel, as well as to itself, are given. The investigation was extended to include joining of thin to thick, thin to thin, and thick to thick sections by the same method. The welding variables studied were the following: type of current, type of gas, gas flow, type of electrode, arc length, arc current, arc voltage, air eddy currents, travel speed, cleanliness of joint, joint fit, joint design, cleanliness of electrode, and method of starting the arc.

The following conclusions are drawn:—

(1) All the materials investigated are weldable by the inert-arc method.

(2) Correct joint fit-up is one of the most important factors in obtaining a strong, leak-tight joint. Wherever possible, a press fit is recommended.

(3) The joint should be free of grease, oil and dirt. A vapour-degreasing treatment, with an agent such as trichlorethylene, is recommended.

(4) For joining tubing up to 0·030-in. wall thickness the electrode size should not exceed 0·040 in. This ensures a favourable electrode current density, which is required for welding of thin sections.

(5) The use of zirconium-oxide-coated or thoriated-tungsten electrodes resulted in a more stable arc. Arc wander is minimized, due to the increased emissivity of the electrode.

(6) Sounder weld deposits were obtained in nickel by the use of helium than with argon, but only an 80-20 argon-hydrogen mixture produced porosity-free welds.

(7) When welding light sections of Type 347 stainless steel argon was preferred to helium, because the arc voltage was lower and, consequently, for a given value of welding current, less heat energy was developed by the arc.

(8) For materials other than nickel, the use of the special shielding eliminated air eddies round the arc, and in this manner it was possible to make sound welds consistently on very thin sections.

(9) A radio-frequency pilot-spark starting unit was preferred to the use of either a carbon pencil or touching the electrode to the work. Burn-throughs were minimized by using spark starting.

(10) The types of inert-arc welding machines described in the paper are considered to be highly suitable for both research and production use. Current values ranging from $\frac{1}{2}$ to 150 amp. and spindle speeds from $\frac{1}{4}$ to 2500 r.p.m. permitted investigation of inert-arc welding over a wide range of current and travel speeds, on cylindrical parts of various diameters.

Conditions found to be optimum for all the materials are shown in tables.

Welding of Nickel and Nickel Alloys

See abstract on p. 11.

ELECTRODEPOSITION AND OTHER COATING METHODS

Cleaning of Metals Prior to Electroplating: A.E.S. Research Report

H. B. LINFORD and E. B. SAUBESTRE: 'Cleaning and Preparation of Metals for Electroplating. IV. Degreasing Evaluation Tests: Sequential Testing.' *Plating*, 1951, vol. 38, Nov., pp. 1157-61; Dec., pp. 1263-6.

The object of the work reported in this paper was the comparison of the relative sensitivities of various degreasing-evaluation tests. In the 'sequential testing' method a cleaned panel is consecutively examined by a series of tests and their efficiency is compared.

A number of degreasing-evaluation methods have been reported in the literature. They fall, broadly, into two categories, (1) those which evaluate directly the condition of the metal surface, and (2) those which examine the physical and chemical characteristics of the cleaner, to give indirect evidence of cleaning performance. A table in this report gives reference to publications relating to various types of quantitative test, and attention is also directed to some direct-type qualitative tests which have been referred to in the literature.

In the tests made by the authors, the relative sensitivity of the tests in detecting residual soil after alkaline cleaning was found to be: atomizer > fluorescent dye > spray pattern (water break) > potassium ferricyanide paper > copper-sulphate dip. Radioactive-tracer, and 'residue-pattern' tests were not included in the experiments, for reasons which are explained.

Plating Practice in U.S.A.: Productivity Report

ANGLO-AMERICAN COUNCIL ON PRODUCTIVITY: 'Metal Finishing.' Report of Specialist Team representing the British Metal Finishing Industry: *published by the Council*, Nov., 1951; 75 pp. Price 3/6.

The team making this report was representative of users, plant manufacturers and raw-material manufacturers. Its members spent six weeks in the U.S.A. in August and September, 1950, paying visits to plants which ranged in size from small jobbing establishments to plants of some of the largest organisations in the country. The visit also included comprehensive discussions with individuals or groups of American specialists in the various branches of the finishing industry. The investigations made were confined to two main classes of metal-finishing process: (1) painting, and (2) electroplating (including related processes such as metal-colouring, anodizing, chemical dipping, etc.). The main function of the team was to collect as much technical information as possible on American methods, and to compare such methods with those currently used in the U.K.: an ancillary aim was to acquire information on factory organisation, management-labour relationships, research, etc., in so far as these aspects affect efficiency and productivity. The data collected, considered in relation to British conditions and potential improvements, lead to general recommendations for (1) fuller mechanization of metal-finishing operations; (2) release to all staff of fuller information on costs; (3) better education of industry and the public with regard to significance of finish and finishing operations; (4) closer collaboration between design and finishing departments; (5) consideration of the adoption, in U.K., of American 'kerb-side' standard of finish, with due safeguards against sacrifice of durability; (6) greater attention to methods of process- and quality-control.

Specific recommendations with regard to the plating industry include emphasis on the advantages of automatic and semi-automatic polishing equipment; the economic value of pre-polished strip for plating; the use of barrelling processes for de-burring and polishing small components; the use of semi-bright nickel-plating processes; appreciation of the potential value of electropolishing and electrobrightening methods; improved metal-cleaning and -rinsing facilities; closer attention to water supplies used in plating solutions; better layout of plating shops. The team also considers it desirable that 'the appropriate authorities should explore the desirability and practicability of instituting a co-ordinated electrodeposition research scheme, with immediate open publication of results, on the lines of the scheme operated by the American Electroplaters' Society'.

A section of the report reviews methods used for electrodeposition of individual metals: that relating to nickel (pp. 30-33) includes a condensed but informative summary of observations made with regard to the use in U.S.A. of bright-nickel plating, from (1) organic solutions, (2) cobalt- or alloy-type solutions, and (3) baths depositing semi-bright coatings. Comment is also made on the very general use, in America, of activating dips, to prepare nickel-plated articles for chromium plating, and on the types of anode and anode bags favoured there.

Nickel-Amalgams

F. PAWLEK: 'Magnetic Properties of Amalgams of the Iron Metals.' *Zeitsch. für Metallkunde*, 1950, vol. 41, Dec., pp. 451-53.

Electrodeposition of iron or cobalt on mercury cathodes does not give rise to formation of amalgams: only suspensions of fine metallic powders in the mercury are found. After separation of the mercury by vacuum distillation the powders, which are strongly pyrophoric, exhibit permanent-magnet characteristics. Electrodeposition of nickel on a mercury cathode results, however, in formation of an intermetallic compound which probably has a hexagonal lattice, and which decomposes, at 450°C., giving a nickel powder which is pyrophoric and also has permanent-magnet properties. On deposition of manganese an amalgam is formed which has a cubic-face-centred lattice: this also decomposes at 450°C., giving metallic manganese. The true amalgams are non-magnetic.

Hardness Testing at Elevated Temperatures: Hot-Hardness of Electrodeposited Nickel

See abstract on p. 4.

Structure of Electrodeposited Nickel-Palladium Alloys

Y. D. KONDRASHEV *et al.*: 'X-Ray Structure Studies of Disperse Precipitates of Nickel-Palladium obtained by Electrolysis.' *Doklady Akad. Nauk S.S.S.R.*, 1951, vol. 78, pp. 729-31: *Chemical Abstracts*, 1951, vol. 45, p. 8317.

Investigation of the characteristics of alloys over a wide range of content, deposited from complex solutions containing palladium chloride, nickel sulphate, sodium nitrite and ammonium sulphate, acidified with a small amount of sulphuric acid. A good summary of the findings is given in *Chemical Abstracts*, *loc. cit.*

NON-FERROUS ALLOYS

Sigma Phase in Binary Alloys of the Transition Elements: Explanatory Hypothesis

A. H. SULLY: 'The Sigma Phase in Binary Alloys of the Transition Elements.' *Jnl. Inst. Metals*, 1951-52, vol. 80, Dec., pp. 173-9; *Advance Copy* 1339.

On the basis of experimental work, correlated with observations reported by other investigators, the author considers that the appearance of the sigma phase in alloys of elements of the First Long Period can be satisfactorily accounted for if it is assumed that the incidence of this phase is determined by a critical excess of electrons in bond orbitals over vacancies in the 3*d*. atomic orbitals. In the alloys of cobalt and iron with chromium; iron, nickel and cobalt with vanadium, and chromium and vanadium with manganese, predictions of the boundary of the homogeneous sigma-phase region can be made on the basis of this hypothesis, to accord well with experimental data, where these are available. The fact that the sigma field does not include the equiatomic composition in certain alloy systems is also explained. It is considered probable that sigma phases occur in alloys between transition elements of the other long periods. The evidence on which the above conclusions are based is succinctly presented, in relation to the respective alloy systems studied by the author and others. Full bibliographical reference is given to original work on the respective systems. Papers relating to the nickel-chromium and nickel-vanadium systems have been reported in *The Nickel Bulletin* at the times of publication.

Nickel-Chromium Equilibrium Diagram

D. S. BLOOM and N. J. GRANT: 'Chromium-Nickel Phase Diagram.' *Jnl. of Metals*, 1951, vol. 3, Nov. (*Trans. Amer. Inst. Mining and Metallurgical Engineers*), pp. 1009-14; T.P. 3155 E.

The authors suggest that, due to certain limitations in the purity of the metals used, especially the chromium, the diagram of this system presented in 1937 by JENKINS *et al.* should be accepted with reservation (see *Jnl. Iron and Steel Inst.*, 1937, vol. 136, pp. 187-220). Special attention is drawn, for example, to the fact that the presence of the compound Cr_2Ni, reported by those authors, remains unverified, and is incompatible with the simple eutectic diagram.

The materials used in the present authors' research were of a higher degree of purity than those available to earlier investigators: the nickel is reported as having a nominal purity of 99·87 per cent., while the electrolytic chromium gave, on analysis, 99·03 per cent. chromium, the major impurity being 0·5-0·7 per cent. of iron. All the alloys were melted in a vacuum furnace, to remove dissolved gases, sufficient carbon being added to the charge to combine with all the oxygen, as carbon monoxide. Final analysis showed carbon about 0·02 per cent. and oxygen about 0·06 per cent. or rather more.

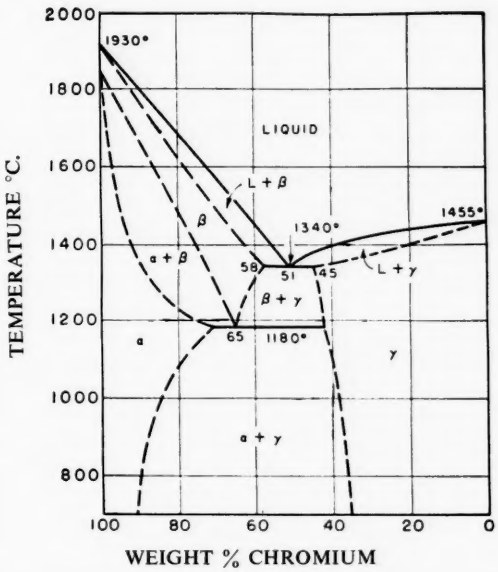


Fig. 1. Chromium-Nickel Diagram.

The phase diagram which eventuated from the investigation is shown above, Fig. 1. The α field is the body-centred-cubic chromium solid solution; the γ field is the face-centred nickel phase, and the β phase is a proposed high-temperature chromium structure, thought to be face-centred cubic. A series of photomicrographs of typical alloys throughout the series is given in the paper.

The results show that a transformation occurs in chromium at about 1830°C.: it is tentatively identified as a change from a body-centred-cubic to a face-centred-cubic structure. Addition of nickel gradually lowers the transformation temperature, until at about 65-35 per cent. chromium-nickel there is a eutectoid temperature of about 1180°C. In alloys having approximately the eutectoid composition and quenched from above the eutectoid temperature, it is possible to produce a body-centred tetragonal metastable structure. This transformation was confirmed by means of a high-temperature X-ray camera, as well as being found by dilatometric and photomicrographic examination.

Solid-Solution Nickel-Alloy Systems

I. I. KORNILOV: 'Solid Solutions of Nickel.' *Izvest. Akad. Nauk S.S.S.R., Otdel. Khim. Nauk*, 1950, pp. 582-9; *Chemical Abstracts*, 1951, vol. 45, p. 7505.

'A theoretical study was made of the number and nature of ternary and more complex equilibrium diagrams involving nickel solid solutions. There are 15 possible ternary continuous solid-solution systems and 20 possible quaternary systems. There are 325 possible ternary systems involving partial solubility with both of the alloying elements and 208 systems involving continuous solid solubility with one element and partial solubility with the other. There are 2600 possible quaternary systems involving partial solubility with all three alloying elements, 2600 with two and 390 with one, the remaining alloying elements forming complete solid solutions with nickel.'

Heats of Formation of Binary Nickel Alloys

T. HEUMANN: 'Effect of Atomic Volume on the Heat of Formation of Solid Solutions of Binary Metallic Systems.' *Zeitsch. für Metallkunde*, 1951, vol. 42, June, pp. 182-9.

Distortion-energy data are calculated for the systems silver - copper, cadmium - zinc, potassium - caesium, sodium-potassium, gold-copper, silver-gold, copper-nickel, gold-platinum, nickel-platinum, gold-nickel, bismuth-antimony, and aluminium-zinc, based on simple lattice models.

Nickel-Amalgams

See abstract on p. 8.

Nickel Silver Casting Alloys: Compositions, Properties, and Uses

J. S. VANICK: 'Nickel Silver Castings.' *Foundry*, 1951, vol. 79, Nov., pp. 92-5, 254-8.

This article discusses composition, treatment, properties and uses of cast nickel silvers containing copper and zinc, with nickel varying between about 6 and about 30 per cent., with or without other elements added to confer special properties. Compositions covered by A.S.T.M. specification B 149-49 are given, and compositions of cast nickel silvers used for specific applications are tabulated. The author briefly summarizes the individual effects of tin (strengthening and hardening ingredient), lead (conferring machinability), and zinc (deoxidizing influence but weakening effect if present in excess). The advantage of increasing nickel content in bleaching is also mentioned: the 20 per cent. nickel alloy is characterized by a silvery shade. Nickel also has a progressively beneficial influence on resistance to corrosion, and the 20 per cent. alloy has a good degree of resistance to seawater, fresh water and indoor atmospheric attack.

The pleasing colour of the nickel silvers has led to increasingly wide use, and this article is illustrated by photographs of a wide range of castings made in various grades of the alloys, both of the straight nickel-copper-zinc type and of alloys in which small amounts of tin, lead, iron, or manganese were present in differing combinations and proportions. Properties typical of some of these alloys are shown.

In connexion with foundry practice and composition of the charges, the following are given as preferred maximum impurities in nickel silver alloys:—iron 0·50, manganese 0·25, silicon 0·05, sulphur 0·035, carbon 0·10, per cent. Particular attention is directed to the harmful influence of silicon. Good deoxidation and accurate temperature control in melting and pouring are highly desirable. Moulds suitable for nickel silvers are of the type used in general bronze-foundry practice, and recent large-scale development of the plaster-mould process for production of nickel silver alloys has led to achievement of smooth surface finish at low cost.

Certain of the nickel-modified 60-40 type brasses resemble the manganese bronzes in the high strength properties which they develop in the cast or forged condition. For example, a 15 per cent. nickel alloy of this class shows tensile strengths up to 85,000 p.s.i. (38 tons per sq. in.), with 20 per cent. elongation. An alloy in this category which contains 12-15 per cent. of nickel is used for propellers.

A further group of nickel silvers is the die-cast or forged type. These high-strength materials contain about equal parts of copper and zinc, with some 6, 10 or 15 per cent. of nickel. An alloy of white colour, characterized by high hardness and wear-resistance, is much used in hardware, sanitary equipment and other fixtures. Good corrosion-resistance is a further property which widens the range of application.

Typical uses of nickel silver casting alloys include ornamental plaques, fittings, etc., internal structural parts in buildings, plumbing fixtures and other hardware, passenger and dining car fittings, marine fittings, household ware, and food-handling equipment.

Wear and Friction Properties of High-Nickel Alloys

R. L. JOHNSON, M. A. SWIKERT and E. W. BISSON: 'Preliminary Investigation of Wear and Friction Properties under Sliding Conditions of Materials Suitable for Cages of Rolling-Contact Bearings.' *Nat. Advisory Committee for Aeronautics, Tech. Note* 2384, June, 1951; 33 pp.

Most of the bearings employed in turbine-type aircraft engines are of the rolling-contact type. Early service experience indicates that the frequency of turbine-bearing failures presents a serious problem, one of the principal sources of failure having been found to be the cage (separator or retainer), where lubrication failures occur at the cage-locating surfaces, arising from several factors, which are discussed in this report. The trend in design of turbine-type engines towards higher operating temperatures, higher surface speeds and less viscous lubricants will increase the severity of the cage problem for rolling-contact bearings.

With a view to solving the problems envisaged, an attempt is being made to obtain a more satisfactory cage material, i.e., one which has a less pronounced tendency towards metallic adhesion to steel under conditions of marginal lubrication than the materials at present in use (brass, various bronzes, Monel and

silver-plated bronze), but has equally good mechanical properties.

The materials selected for the tests reported (carried out at the N.A.C.A. Lewis Laboratory) were chosen on the basis of both present and anticipated requirements: they comprised brass, beryllium-copper, Monel, bronze, Nichrome V, aluminium alloy, spheroidal-graphite (nodular) cast iron, and grey cast iron. The sliding-friction tests were not simulated cage tests, but were made to obtain fundamental comparative information on friction and wear properties, which are a general measure of adhesion under sliding contact. All were tested in contact with S.A.E. 52100 chromium steel.

In such service the ability of materials to form surface films which prevent welding is a factor of major importance under both dry-friction and boundary-lubrication conditions. In the cast irons such films were supplied from within by graphitic carbon, and in the bronze the lead functioned in the same manner. Under both dry and lubricated conditions Monel, Nichrome V and beryllium-copper formed films, believed to be oxides: when present, such films improved the performance of the materials. When run dry the cast irons showed the least wear and the least tendency towards surface welding of any of the materials investigated, and the same observation was made under boundary-lubricated conditions, where it was established that the cast irons had the highest load capacities of all the materials. Attention is directed to the superiority of the properties of nodular (magnesium-treated) cast irons over those of ordinary grey cast iron.

Performance of Monel and of Nichrome V depended on whether or not a film was present: the materials with films had relatively high load capacity when boundary-lubricated. Bronze showed the lowest coefficient of friction under dry sliding conditions, but was subject to surface failure and increasing friction as the sliding conditions became more severe. Brass, beryllium-copper and the aluminium alloy showed continuous failure under all conditions used in these tests, and are considered to be entirely unsuitable for the service in question.

Welding of Nickel and Nickel Alloys

E. G. WEST: 'The Welding of Non-Ferrous Metals.' *Published by Chapman and Hall, Ltd., London*, 1951; 553 pp. Price 55/-.

The author points out in his preface that although the welding of steel is a well-documented subject, reliable information on non-ferrous metals has, until recently, been more difficult to obtain. This book has been written to place on record basic information and the results of practical experience in welding of the various forms of non-ferrous metals and alloys. Two main classes of reader are envisaged: (1) the welding engineer, operator, instructor or trainee, and (2) the designer, engineer or metallurgist, i.e., the man who, while not operating the welding process, must have an adequate knowledge of the technique and effects of welding, in order that his own work may link satisfactorily with that of the welder, to produce a sound and stable component or structure.

The sequence of the book is from general principles to specific applications, dealing first with the quality 'weldability' and the properties important in a material which is to be welded. These chapters are followed by a summary discussion of fusion-welding processes (gas, metallic-arc, carbon-arc, atomic hydrogen, and inert-gas-shielded arc). Equipment for, and technique and range of application of, the respective methods are outlined, reference being directed, for fuller information, to the many standard books on welding now available. The general chapters are completed by a treatment of resistance-welding processes, and pressure welding.

The second part of the book is devoted to chapters on the welding of individual groups of metals and alloys: methods suitable for the following materials are described:—aluminium and its alloys; magnesium alloys; copper and its alloys; nickel and nickel alloys (including the Monel group, Inconel, Inconel 'X', the Hastelloy alloys, Illium, nickel-chromium alloys, Nimonic alloys, and nickel-iron alloys); lead and its alloys; low-melting-point metals; high-melting-point metals; precious metals.

The text is well supported by references to the literature, which is listed in a *bibliography* of 353 items.

Seam Welding of Monel

E. F. NIPPES and G. M. SLAUGHTER: 'Seam Welding of Monel Metal.' *Welding Jnl.*, 1951, vol. 30, Nov., Suppl. pp. 537-44.

In 1939 a long-range programme was initiated at the Welding Laboratory of the Rensselaer Polytechnic Institute, to establish optimum resistance-welding conditions for nickel and high-nickel alloys. The research, which has been continued up to the present time, has been sponsored by The International Nickel Company.

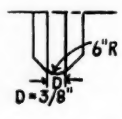
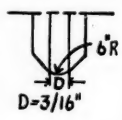
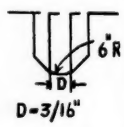
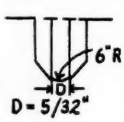
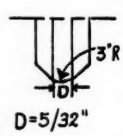
Previous reports from the Institute have covered spot, flash, and cross-wire welding practice for high-nickel materials: the present paper deals with optimum seam-welding conditions for five thicknesses of Monel sheet (0·062, 0·031, 0·021, 0·015 and 0·010 in.). The recommendations made, based on work of which details are given in the report, are summarized in the table on p. 12.

The authors discuss at some length experiments made to determine optimum electrode force, weld time, weld 'off' time, weld spacing, and welding current.

In view of the fact that much of the difficulty which has been experienced in seam-welding Monel has been associated with sticking of the sheet to the electrode during welding, a special study was made of the problem. Examination of various possible methods of alleviation showed that the only one of sufficient value to allow of welding the thinner gauges was surface hardening of the electrode wheels by cold working, which appears to obstruct bonding and thus minimizes sticking. Method of hardening, by means of a burnishing tool, is described: the tool is illustrated. Some reduction of sticking was also found to result from the use of higher pressures.

The pillow test was selected for evaluation of the strength and pressure tightness of the welds made

Recommended Seam-Welding Conditions for Monel

Set-up Variables			Welding Variables					Fusion Analysis			
Thickness and Gauge of Monel Sheet	Electrode Shape	Electrode Force lbs.	Timing Cycle 'On' Time	Timing Cycle 'Off' Time	Weld Spacing Welds /in.	Wheel Speed in./min.	Welding Current amps.	Width of Fused Zone in.	Weld Overlap %	Weld Penetration %	
0·062 in. 16		2,500	8	12	9	20	19,000	0·17	10	35	Optimum
		2,400-2,600	6-10	8-15	7-11	—	16,000-21,000	0·0-0·25	0-15	0-40	Permissible range
0·031 in. 22		700	4	12	12	19	10,000	0·15	20	40	Optimum
		600-800	3-6	8-15	10-14	—	8,500-11,000	0·0-0·18	0-25	0-45	Permissible range
Electrodes Unburnished 0·021 in. 25		600	3	12	11	22	9,500	0·15	10	35	Optimum
		500-700	2-4	8-15	10-12	—	8,000-10,000	0·0-0·18	0-15	0-40	Permissible range
Electrodes Burnished 0·021 in. 25		500	2	6	12	38	8,700	0·15	20	40	Optimum
		400-600	1-3	4-8	10-14	—	7,200-8,900	0·0-0·18	0-25	0-50	Permissible range
Electrodes Burnished 0·015 in. 29		300	1	3	12	75	7,600	0·10	15	35	Optimum
		250-350	½-1½	2-4	11-13	—	6,800-7,800	0·0-0·11	0-20	0-40	Permissible range
Electrodes Burnished 0·010 in. 32		200	1	3	12	75	5,300	0·09	15	30	Optimum
		150-250	½-1½	2-4	11-13	—	4,800-5,500	0·0-0·10	0-20	0-35	Permissible range

under the recommended conditions, being chosen as the only test which approximately simulates operating conditions in a seam-welded joint.

K Monel Liquid-Oxygen Tanks

'Missile Nickel.' *Steel*, 1951, vol. 129, Oct. 29, p. 63.

Liquid-oxygen tanks used on certain types of guided missile present a complex problem of strength-temperature relationships. Pressure is high, combined with a temperature of 200°C. below zero, i.e., sufficiently low to cause embrittlement in many materials. One manufacturer of such tanks has specified K Monel, since the toughness and ductility of this alloy are unaffected at the temperature of liquid oxygen, and the tensile strength of the material is actually higher at the sub-zero than at normal temperature.

Nickel and Nickel-Cobalt Catalysts for the Fischer-Tropsch Synthesis

See abstract on p. 6.

Magnetostriction in Nickel-Palladium Alloys

Z. I. ALIZADE: 'New Magnetostriction Alloys Iron-Palladium and Nickel-Palladium.' *Doklady Akad. Nauk. S.S.S.R.*, 1950, vol. 73, pp. 79-81.

Properties of alloys of the above types were compared with those of pure nickel. Particular attention is directed to alloys containing iron 60, palladium 40, per cent., and nickel 62·25, palladium 37·75, per cent. A condensed summary of the observations made is given in *Chemical Abstracts*, 1951, vol. 45, pp. 6983-4.

Structure of Electrodeposited Nickel-Palladium Alloys

See abstract on p. 9.

Solidification Shrinkage of Cadmium-base Alloys containing Nickel

T. SATO and H. KANEKO: 'On the Volume Shrinkage of Some Cadmium-base Alloys.' *Technology Repts. Tôhoku Univ.*, 1950, vol. 14, pp. 30-44.

Report of determination on cadmium-base alloys of the following types:—

Binary alloys containing silver, copper, nickel, mercury.

Ternary alloys containing copper+silver, copper+mercury, copper+nickel, silver+nickel, nickel+mercury.

NICKEL-IRON ALLOYS

Oxidation Characteristics of Nickel-Iron Alloys

J. MOREAU and J. BENARD: 'Study by X-Ray Diffraction of Selective Oxidation of Nickel-Iron Alloys.' *Comptes Rendus*, 1951, vol. 232, May 16, pp. 1842-3.

The experimental data obtained by the authors lead to the conclusion that during oxidation the metallic phase immediately in contact with the oxide layer becomes enriched in nickel, at a rate dependent on the temperature at which the oxidation takes place. This effect is due to the instability of nickel oxide in presence of iron oxide which, because of its non-stoichiometric nature, acts as a vehicle for iron.

Effect of Magnetic Field on Acoustical Properties of Nickel and Nickel-Iron Alloys

See abstract on p. 7.

Electron Tubes: Textbook

See abstract on p. 4.

Welding of Nickel and Nickel Alloys

See abstract on p. 11.

Inert-Arc Welding of Nickel- and Stainless-Steel Tubing

See abstract on p. 7.

CAST IRON

Engineering Properties and Uses of Spheroidal-Graphite Cast Iron

M. M. HALLETT: 'Ductile Cast Iron.' *Trans. Inst. Marine Engineers*, 1952, vol. 64, Advance Copy, Dec. 11, 1951; 6 pp.

The aim of this paper is to review developments in magnesium-treated cast irons, in the light of the author's own experience, and to provide a practical summary of the information now available on the characteristics of the irons, paying particular attention to the properties likely to be of particular interest to marine engineers. Brief reference is also made to the cerium process, but it is pointed out that at the present stage of development this method of producing nodular-graphite cast iron is of strictly limited application.

Introductory notes comprise a discussion of the reasons for the improvement in mechanical properties effected by the change from flake to spheroidal graphite, with emphasis on the high proportion of the graphite which is present in spheroidal form in a correctly treated iron. It is found that by careful metallurgical control, an 80-90 per cent. proportion can readily be achieved in large-scale production.

It is suggested that the term 'ductile' should be restricted to the iron in the annealed condition, in which it shows appreciable ductility. The progressive effect of time of annealing at 725°C., on the chief mechanical properties of a spheroidal-graphite cast iron, is considered in some detail, and is demonstrated by a set of curves showing change in tensile strength, hardness, impact strength and elongation, for annealing times up to 20 hours. Test results quoted as typical of those regularly obtained under commercial production conditions are shown in the table on p. 14, in comparison with properties typical of ordinary grey cast iron.

The author also gives a summary of information, based on authoritative literature and on his own experience, with regard to ductility as shown by torsion tests, impact strength (and the method of its determination on ductile cast irons), fatigue-resistance, and compressive strength.

It is pointed out that while in all cast irons mechanical properties tend to fall with increasing size of casting, the amount of the decrease is less in spheroidal-graphite irons than in other types: the mechanical properties quoted in the table (see p. 14) are stated to be typical of castings having a sectional thickness of 1-2 in., at which size tensile strengths of 35-45 tons per sq. in. may reasonably be expected in the 'as-cast' condition. After annealing, the values are of the order of 30-34 tons per sq. in., with elongation ranging from 10 to 20, and averaging at least 12, per cent.

Some data are quoted for the magnetic and electrical characteristics of spheroidal-graphite irons: the combination shown suggests possible applications of the irons for electrical purposes, e.g., pole pieces of electromagnets.

In a later section of the paper the author considers

Mechanical Properties of Spheroidal-Graphite Cast Iron

	Grey Cast Iron	Spheroidal-Graphite Iron	
		'As Cast'	Annealed
Limit of proportionality, tons per sq. in.	—	14·0	16·0
0·1 per cent. proof stress, tons per sq. in.	—	31·5	24·8
Yield point, tons per sq. in.	—	—	27·0
Maximum stress, tons per sq. in.	15·8	37·0	32·0
Elongation, per cent.	—	1	21
Reduction in area, per cent.	—	1	21
Modulus of elasticity, $\times 10^6$ lb. per sq. in.	16·7	24·0	24·0
Vickers diamond hardness	229	296	190

the properties of cast iron which are influenced to an important extent by surface condition: heat-resistance and resistance to oxidation; corrosion-resistance; wear-resistance. With regard to oxidation-resistance, it has been shown that the much shorter path offered to oxidizing gases by spheroidal-graphite particles (as compared with particles of flake form) markedly improves resistance to scaling. The new irons appear to have improved resistance to dilute solutions of hydrochloric and sulphuric acids, but in corrosion depending mainly on absorption of oxygen the differences in rate of attack between spheroidal-graphite and flake-graphite irons are probably not significant. An overall conclusion which, however, would seem to be amply justified, is that spheroidal-graphite cast irons can safely be employed in all mildly corrosive conditions in which flake-graphite irons have already proved suitable.

In discussing the wear-resisting qualities of spheroidal-graphite cast iron, the author quotes test results on large piston rings (550 mm. dia.) fitted in a marine Diesel engine. After 6,000 hours' running it was found that the rate of wear of the spheroidal-graphite iron rings was only two-thirds that of normal piston-ring grey cast iron. He also quotes results of tests under conditions of dry loading, in which resistance to galling of spheroidal-graphite iron was superior to that of ordinary grey cast iron. In other tests, however, in which wear under heavy load was tested, using boiling water as 'lubricant', the spheroidal-graphite iron proved inferior to a flake-graphite type, suggesting that while as-cast spheroidal-graphite iron may function satisfactorily under normal lubrication, care should be taken before applying the annealed material under conditions from which lubrication is virtually absent.

The magnesium treatment has also been applied with success to high-alloy cast irons of the Ni-Resist type. Results quoted on spheroidal-graphite Ni-Resist, in the 'as-cast' and heat-treated conditions, indicate that the magnesium treatment doubles the mechanical strength of the iron (as-cast 24-25 tons per sq. in.; air-cooled from 1000°C. 26-27 tons per sq. in.), providing a material having a valuable combination of strength and corrosion-resistance.

The author briefly discusses the production properties of the new irons, emphasizing on the basis of personal experience, that, given sound foundry technique and accurate control, satisfactory castings can consistently be obtained.

In discussing the applications of spheroidal-graphite irons in marine engineering it is pointed out that their uses fall into three main fields:

Those in which use is made of its improved shock-resistance.

Those requiring high strength, often combined with resistance to wear.

Those in which heat-resistance is combined with other properties, such as wear-resistance.

Attention is directed to the potential value of the irons in underwater conditions involving shock, and their possible usefulness in propellers is suggested. The Diesel-engine field is also considered as an interesting outlet for the new irons; large pistons (750 mm. diameter) are already undergoing service tests.

Wear and Friction Properties of High-Nickel Alloys

See abstract on p. 10.

Spheroidal-Graphite Cast Iron in Steel Mill Equipment

'Ductile Iron Makes Good in Steel Mill Equipment.' *Nickel Topics*, 1951, vol. 4, No. 8, p. 5.

It is reported that cooling-bed lifter bars of ductile cast iron have appreciably reduced breakage formerly experienced with ordinary grey-iron bars, and that a 25 per cent. increase in the overall average life has resulted from the use of the new iron in lifting plates of coil-annealing furnaces. Properties typical of the 1-in. bar tests on the iron used for the latter purpose include 85,000 p.s.i. tensile strength (38 tons per sq. in.) and 5 per cent. elongation.

Another application for ductile iron is for bearings of run-out table rolls on a 60-in. cogging mill. Ductile-iron bearings, in comparative test with bearings of the bronze composition normally used for this purpose,

showed a three-fold improvement in life and had the further advantage of costing only one-third as much. Following this experience, a large mill in U.S.A. has standardized, for the bearings, on a grade of iron showing the following properties: tensile strength 75,000 p.s.i. (33·5 tons per sq. in.): hardness 180 Brinell: elongation on 2 in., 15 per cent.

CONSTRUCTIONAL STEELS

Surface Defects in Ingots: Handbook on Terminology

BRIT. IRON AND STEEL RESEARCH ASSOCN.: 'Surface Defects in Ingots and their Products (Recommended Definitions).' *Iron and Steel Inst. Special Report* 44, 1951; 51 pp.

The terms of reference of the Ingot Surfaces Sub-Committee of the B.I.S.R.A. Steelmaking Division are the following:—

> 'To examine data on, and to investigate the causes of, ingot surface defects and their influence on the semi-finished and finished product.'

In carrying these terms of reference into effect it was found that much confusion existed with regard to the names given in the industry to various forms of defect. The present report has been compiled in an endeavour to clarify designation.

Part I deals with defects present in the ingot, Parts II and III with those in semi-finished and finished products. In each case typical examples are illustrated, and recommendations are made as to the most suitable terminology. Alternative forms of designation used in the industry are also recorded. Although nomenclature is the primary subject, some brief indication is given, in most cases, of the cause, as well as the nature, of the defects.

Defects peculiar to the manufacture of steel sheet, strip and wire are not included, since the Committee considers that their specialized nature warrants separate treatment.

British Standard 'Emergency' Case-Hardening Steels

See abstract on p. 2.

Influence of Hydrogen on Ductility of Nickel-Alloy Steels

J. D. HOBSON and C. SYKES: 'Effect of Hydrogen on the Properties of Low-Alloy Steels.' *Jnl. Iron and Steel Inst.*, 1951, vol. 169, Nov., pp. 209-20.

It has already been established that the ductility of steel, as measured by the tensile test, is reduced if significant amounts of hydrogen are present, and it is generally agreed that this brittleness may be an important factor in the formation of hair-line cracks, snow-flakes, fish-eyes, and related defects.

No work has previously been carried out to determine whether the effect of hydrogen varies from cast to cast of a given steel, and no systematic investigation has been made of the relation between tensile strength of the steel and intensity of embrittlement. The work described in the present paper deals with these two aspects of the problem.

Various methods have been adopted for controlled introduction of hydrogen into steel: these are briefly reviewed by the authors. The method used in their experiments was treatment at temperatures up to 600°C. in hydrogen, at elevated pressures: the amount of hydrogen introduced was controlled by varying the pressure and temperature of treatment. The impregnation could be achieved without significantly modifying the structure and mechanical properties of the specimens. A description of the apparatus and modus operandi is given, with illustration. Some of the steels were electrolytically hydrogenated, for comparison with results obtained with specimens hydrogenated by the high-pressure method.

The steels on which the investigation was made were mainly of the types used for production of large forgings: they included typical 3 per cent. Cr chromium-molybdenum; 3½ per cent. nickel, 0·4 per cent. carbon; 1 per cent. nickel, and 2½ per cent. Ni nickel-chromium-molybdenum grades.

The observations made and the results of the tests recorded on the steels in various conditions confirm the correlation existing between ductility and hydrogen content of low-alloy steels. Although there is some loss of notched-bar impact strength in steels containing hydrogen, the main effect of the occluded gas is reflected in loss of ductility. Hydrogen has little effect on the shape of the tensile stress-strain curve, but its presence results in fracture of the test piece before elongation and necking reach normal values. Thus the true tensile stress, calculated on the area at the point of fracture, neglecting tri-axial stresses due to the neck, is reduced by the presence of hydrogen, but since fracture usually occurs only after appreciable reduction of area, there is no effect upon the apparent maximum stress.

The effect of hydrogen appears to be identical whether introduced by electrolysis or by high-pressure treatment, and the magnitude of the embrittlement was found to be remarkably consistent in different casts of a 3 per cent. Cr chromium-molybdenum steel of the same tonnage.

It is concluded that for small ruling sections (up to 6 in. diameter), the amount of hydrogen likely to be present in fully treated material (less than 1 ml./100 g.) will not have any important effect on ductility, even at the highest tonnage. In forgings, transverse and radial ductility in the body may be significantly reduced if steps are not taken to reduce the hydrogen content below 2 ml./100 g.

Embrittlement data for the four forging steels examined, on the basis of longitudinal tests at a level of 50 tons per sq. in. tensile strength, are shown graphically. With regard to formation of hair-line cracks, the carbon steel proved least susceptible, the chromium-molybdenum steel was intermediate, and the 3½ and 1 per cent. nickel steels were similar, being the most susceptible. With high hydrogen content (approx. 9 ml./100 g.) the nickel steels showed less reduction in area than the carbon steel, but at 2-4 ml./100 g., which is the level of hydrogen content to be

expected in forgings, the differences in reduction in area bore no relation to the hair-line crack susceptibility of the materials.

Transverse and radial figures for reduction in area obtained from test pieces cut from forgings corresponding to the high hydrogen contents (9 ml./100 g.) appear to be still adequate to prevent the completely brittle fracture typical of hair-line crack separations, and the outstanding consistency of the embrittling effects of hydrogen is in marked contrast to the erratic nature of the hair-line crack phenomena.

Previous heat-treatment of the steel plays an important part in determining the extent of embrittlement: results suggest that there is an optimum tempering temperature producing minimum susceptibility to embrittlement. Both hardened and spheroidized specimens are prone to embrittlement.

Indications are that hydrogen content does not alone decide whether or not hair-line cracks form. It has, however, an embrittling effect, particularly in the presence of stress raisers, emphasizing the importance of steelmaking and processing methods which ensure material of low hydrogen content.

Sub-Zero Impact Properties of Stainless Nickel-Chromium and High-Nickel Steels

See abstract on p. 25.

Surface Hardening of Steel

G. T. COLEGATE: 'The Surface Hardening of Steel. Part X. Cyaniding Practice.' *Metal Treatment and Drop Forging*, 1951, vol. 18, Nov., pp. 507-14.

This instalment of the series opens with a consideration of composition and operation of pure-cyanide case-hardening baths, and maintenance procedure. The effect of mass on case depth obtainable by cyanide hardening is discussed, with regard to treatment in both activated and straight cyanide mixtures. Typical effects producible on nickel-alloy and other steels are graphically illustrated, and the factors affecting the depth of the case are reviewed. Variation in carbon: nitrogen ratio at different depths is also considered, and recommendations are made on post-cyaniding treatment.

The advantages of cyaniding, vis-à-vis solid carburizing, are freedom from scale, absence of serious distortion, ease of temperature control, more uniform case depth, less risk of exfoliation, ease of operation, and the possibility of direct quenching. Minor disadvantages associated with cyanide treatment, which must be recognized but do not outweigh its advantages, are the poisonous nature of the cyanide, tendency to formation of a deposit at the liquid level on parts treated in activated baths, and the relative brittleness of the case produced by cyanide hardening.

Some specialized case-hardening processes closely allied to cyaniding are also briefly discussed:—'Chapmanizing', dry cyaniding, and the 'Ni-carb' process. Various methods of cyaniding have been put forward in which ammonia is bubbled through the molten bath during treatment, increasing the proportion of nitrogen present in the case. In the 'Chapmanizing' process good results are obtained by dissociation of the ammonia into active nitrogen and hydrogen before passing into the molten cyanide. The dry-cyaniding process is characterized by introduction of ammonia during gas carburizing, and the 'Ni-carb' process is of a closely similar character. Typical examples of results obtainable by the various 'special' methods are quoted, and reference is made to other modified gas mixtures by which a combined carburizing-nitriding effect is obtained.

Resistance of Nickel-Chromium-Molybdenum Valve Steels to Graphitization

T. N. ARMSTRONG and R. J. GREENE: 'Nickel-Chromium-Molybdenum Steel Valve Casting after 50,000 Hours of Service at 900°F.'* *Reprint of paper to Amer. Soc. Mechanical Engineers;* see abstract in *Nickel Bulletin*, 1951, vol. 24, No. 3, pp. 56-8.

Issued by International Nickel Co., Inc., 1951; 3 pp.

HEAT- AND CORROSION-RESISTING ALLOYS

Constitution and Properties of Cast Heat-Resisting Nickel-Chromium-Iron Alloys

H. S. AVERY, C. R. WILKS and J. A. FELLOWS: 'Cast Heat-Resistant Alloys of the 21% Chromium- 9% Nickel Type.' *Amer. Soc. Metals, Preprint* 15, Oct., 1951; 24 pp.

This paper is one of a series issued under the auspices of the American Brake Shoe Company, on the properties and applications of corrosion- and heat-resisting cast alloys containing iron, nickel, and chromium. For reference to some of the earlier papers in the series see *Nickel Bulletin*, 1947, vol. 20, Nos. 3-4, 7 and 11, pp. 58, 111 and 165; 1950, vol. 23, Nos. 8-9, p. 162.

Castings to the nominal composition chromium 21, nickel 9, per cent. have been regularly produced, although in relatively small quantity, for a number of years; they conform to the 'HF' designation in the Alloy Casting Institute series, and their importance became increasingly obvious during World War II, when the need arose for conservation of strategic materials. Systematic investigations carried out under the National Research Council showed that an alloy of this type could be used in many instances as replacement for alloys of higher nickel and chromium contents, and it has been recognized by inclusion in various authoritative compilations of heat-resisting alloys published during the past few years.

The present paper embodies the results of some additional work which has recently been done, to evaluate more closely the properties of alloys within the normal range of composition to be expected in the 21-9 grade.

Experience gained in the study of the influence of the individual elements on other austenitic alloys rendered relatively easy the selection of the upper and lower limits of each element which should be provided for,

* *We shall be pleased to supply a free copy of this publication.*

Composition of 21-9 Type Alloys Studied

C %	Mn %	Si %	Cr %	Ni %	N %	Expected Properties
0·25	0·96	1·72	22·3	7·7	0·07	Maximum ductility; minimum creep strength
0·25	0·85	0·92	21·2	8·7	0·09	
0·28	0·96	1·15	20·8	9·1	0·09	Mid-range strength and ductility
0·28	0·90	1·13	20·6	9·0	0·09	
0·30	0·86	1·09	19·1	10·4	0·15	
0·34	0·92	0·48	19·3	10·5	0·11	Minimum ductility; maximum creep strength
0·33	0·85	1·08	19·1	10·4	0·14	
0·33	0·86	1·09	19·1	10·3	0·18	

in order to allow for the maximum variation in properties which would occur in this grade of material. The full gamut of composition studied is shown in the table above.

The data presented in the paper cover:—

(1) Room-temperature mechanical properties, in the as-cast condition, and after ageing for 24 hours at 1400°F. (760°C.).
(2) Creep-rupture and standard creep-test data at 1200°, 1400°, 1600° and, in some cases, 1800°F. (650°, 760°, 870° and 980°C.).
(3) Cyclic-temperature effects in creep testing.
(4) Magnetic permeability after various thermal treatments.
(5) Behaviour under conditions of hindered thermal contraction, providing assessment of possible thermal-stress levels over a wide range of temperature, and a qualitative estimate of the hot-ductility of the material.
(6) Oxidation-resistance:
    (i) 100-hour exposures at 1600°F. (870°C.) in an electrically-heated furnace through which air was circulated after saturation with water vapour at 90°F. (32°C.).
    (ii) Exposure at 1940°F. (1060°C.) to intermittent heating in an industrial heat-treating furnace fired alternately with natural gas and with oil.
(7) Hot-hardness as a function of temperature (600°, 800°, 1000° and 1200°F. (315°, 425°, 540° and 650°C.) in various conditions.
(8) Influence of thermal history on structure.
(9) Miscellaneous physical properties (density, melting point, modulus of elasticity, thermal expansion).

The combination of properties revealed by the tests shows that the 21-9 alloy is especially suitable for service in the range 1200°-1600°F. (650°-870°C.), a temperature stage at which the ferritic steels and the heat-resisting cast irons lose strength rapidly and are also unsuitable from other aspects. The cast austenitic grades most commonly used at present in this range (26-12 and 16-35 per cent. chromium-nickel types) are considered to have certain disadvantages: the 26-12 alloy, although showing excellent strength and ductility at 1800°F. (980°C.) or above, has a tendency to embrittle by carbide precipitation at 1400°F. (760°C.), and the 16-35 is relatively costly for use at the intermediate temperatures at which the 21-9 shows a peculiarly attractive combination of ductility, insensitivity to carbide embrittlement, and creep strength. At lower temperatures it is considered to be potentially useful for applications in which a machinable non-magnetic material is required. The 21-9 alloy is not recommended primarily as a corrosion-resisting material, because its relatively high carbon content renders it more susceptible to intergranular attack than the low-carbon 18-8 chromium-nickel-iron grades.

Influence of Composition on High-Temperature Strength of Complex Nickel-containing Alloys

E. E. REYNOLDS: 'The Influence of Chemical Composition on the Rupture Properties at 1200°F. (648°C.) of Wrought Chromium - Nickel - Cobalt - Iron - Molybdenum-Tungsten-Niobium Alloys.' *University Microfilms, Publn. No.* 2451, 1951; 169 pp.

Announced as available (in microfilm or paper enlargement form) in *Microfilm Abstracts*, 1951, vol. 11, No. 2, pp. 371-2.

Influence of Composition and Structure on Creep Strength of Nickel-Chromium-Iron Alloys

A. M. BORZDYKA: 'Creep Properties of Austenitic Alloys in Relation to the Constitutional Diagram.' *Doklady Akad. Nauk S.S.S.R.*, 1950, vol. 75, pp. 37-8; *Chemical Abstracts*, 1951, vol. 45, p. 7503.

'The stress required to produce creep rate of 10^{-6} per hour at 600°C. was determined for 12 binary and 34 ternary alloys in the iron-chromium-nickel system. Alloys in the austenite region had the highest creep strengths, about 8 kg. per sq. mm. (5 tons per sq. in.). Study of alloys containing 25 per cent. chromium with 4-16 per cent. nickel showed that creep strength increases linearly as the microstructure changes from ferrite to austenite. Sigma lowers the creep strength of austenitic alloys.'

Influence of Ageing on High-Temperature Properties of Inconel 'X'

D. N. FREY, J. W. FREEMAN and A. E. WHITE: 'Fundamental Ageing Effects Influencing High-Temperature Properties of Solution-Treated Inconel "X".' *Nat. Advisory Committee for Aeronautics, Tech. Note* 2385, June, 1951; 71 pp.

A report is made of the effects of various ageing treatments on the mechanical properties of solution-treated Inconel 'X' at 1200° and 1500°F. (648° and 815°C.), for rupture times of 0·1 to 1000 hours. The

investigation formed part of a comprehensive research on fundamental factors which control the properties of austenitic alloys showing exceptionally high creep and rupture strengths in the above temperature range. Inconel 'X' was chosen for study as representative of alloys having marked precipitation-hardening characteristics, in contrast with N-155, which had been studied earlier as an alloy which age-hardens only slightly, although subject to considerable precipitation during ageing.

The ageing treatments were carried out at 1200°, 1400° and 1600°F. (648°, 760° and 870°C.), for periods up to 1000 hours. Microstructures developed by such treatments were examined by means of X-ray diffraction studies, and optical- and electron-micrographic examination, and the findings were correlated with mechanical properties.

From the results of these tests, and correlation of the data with those previously obtained on N-155, two distinct classes of austenitic alloy subject to precipitation from supersaturated solid solution were established. In the first, of which low-carbon N-155 is typical, no beneficial effect on creep properties is obtained by ageing and resulting precipitation. This is due to excessive spacing between the particles of the precipitate, and depletion of the matrix of the large 'incongruous' atoms forming the precipitate. In the second type, e.g., Inconel 'X', considerable improvement in creep-resistance at relatively low temperature, 1200°F. (648°C.), was found to result from precipitation, because the precipitate was formed in a certain critical dispersion. For this critical dispersion agreement was found with an extension of the rate theory of creep, which relates logarithmic creep rate linearly to internal stress resulting from the precipitation. At higher temperatures (1500°F.: 815°C.) behaviour of Inconel 'X'-type alloy is similar in nature to that of the N-155 type, inasmuch as spacing of the particles of the precipitate was either initially too large or else rapidly became so.

In both classes of alloy ageing resulted in some improvement in rupture strength in the range of 100 to 1000 hours time-to-rupture at the lower temperature (1200°F.: 648°C.). The improvement in the N-155 alloy was apparently due to formation of a grain-boundary phase: in Inconel 'X' the effect was obtained through increase in resistance to creep before fracture.

Time-Temperature Relationship for Rupture and Creep Stresses in High-Temperature Alloys

F. R. LARSON and J. MILLER: 'A Time-Temperature Relationship for Rupture and Creep Stresses.' *Amer. Soc. Mechanical Engineers, Preprint* 51-*A*-36, Nov., 1951; 7 pp.

Despite the effort which has already been expended in the attempt to discover a relationship between results of short- and long-time tests, results to date have not been satisfactory. Present methods of extrapolation of a log-log plot of stress vs. time-to-rupture are often inaccurate and misleading.

It has been demonstrated by many investigators that creep, tempering and diffusion appear to obey rate-process theories and that the rates are expressible by an equation of the form

$$\dot{\epsilon} = Ae^{-Q(S)/RT}$$

where $\dot{\epsilon}$ is the rate, A is a constant, $Q(S)$ is the activation energy for the process under the conditions considered, R is the gas constant, and T the absolute temperature. HOLLOMAN and JAFFE have shown that the relation between tempering time and temperature for a given hardness, derived from the above equation, is expressed by the following formula

$$T(C+\log t)=\text{const.}$$

where T is the absolute temperature, C is a material constant, and t is time. Since both tempering and creep appear to obey rate-process theories, it was believed by the authors that this concept should be directly applicable in creep- and rupture-testing, for the purpose of shortening the time of testing.

They therefore analyzed a large amount of rupture data, to ascertain to what degree the values complied with the time-temperature parameter $T(C+\log t)$. In this paper a selection of such data is presented, chosen as representative rather than as measurements which showed the best agreement. Three criteria were applied in choice of values, in order to ensure: (1) test results over a wide range of temperature and time; (2) typical alloys covering a wide range of composition; (3) test data which could be considered reliable and free from discrepancies. The material included in the paper relates to low-carbon steel, carbon-molybdenum steel, chromium-molybdenum-titanium steel containing boron; 18-8 and 18-8-Mo chromium-nickel steels; S-590 (complex nickel-chromium-cobalt-base alloy), Haynes Stellite No. 34 (cobalt-chromium-base alloy containing molybdenum), and titanium.

The considerable amount of test data recorded in the paper confirms the validity of the time-temperature relation given above: all values analyzed complied within limits of experimental error. A value of 20 for C was found to be satisfactory for all the materials considered. Application of this relation allows the use of short-time tests to determine long-time data with a close degree of accuracy, and also permits presentation of the complete rupture characteristics of an alloy on a single master curve, thus facilitating comparison with other alloys.

Nickel-Chromium Equilibrium Diagram

See abstract on p. 9.

Thermal Expansion of High-Temperature Alloys

W. R. APBLETT and W. S. PELLINI: 'A Recording Dilatometer for High Temperatures.' *Amer. Soc. Metals, Preprint* 2*W*, Jan.-Feb., 1952; 15 pp.

The paper is primarily concerned with development of a new dilatometric method for which the maximum temperature range is limited only by the availability of temperature-measurement techniques. An example of the scope of its use is given by the fact that the expansion of tungsten up to 4700°F. (2595°C.) has been measured. An illustrated description is given of the equipment and procedure. The instrument embodies a clip gauge constructed from wire resistance strain-gauges. Heating is accomplished by passing high

Table I
Chemical Composition

Material	C %	Mn %	Si %	Cr %	Ni %	Co %	Mo %	W %	Ch %	Ti %	N_2 %	Fe %
N-155	0·17	1·67	0·66	21·0	20·5	30·2	2·43	—	—	—	0·119	Bal.
19-9 DL	0·29	1·00	0·82	19·2	9·0	—	1·34	—	—	—	0·014	Bal.
Inconel X	0·05	0·48	0·48	14·5	74·5	—	—	—	1·0*	2·5*	—	7·0*
E.M.E.	0·15	0·52	0·57	19·5	12·2	—	—	3·25*	1·05*	—	0·127	Bal.
16-25-6	0·10*	1·68	0·50*	16·3	25·2	—	6·25	—	—	—	0·110	Bal.
S.590	0·46	1·20	0·40	20·0	18·7	4·87	1·22	2·20	7·34	—	—	Bal.
HU	0·48	1·13	1·43	17·0	60·3	0·23	0·08	—	0·22	—	0·041	Bal.
HW	0·66	0·67	1·52	17·2	40·0	0·27	0·12	—	0·22	—	0·039	Bal.
Vitallium	0·22*	0·66*	0·53*	27·4*	2·8*	62·2*	5·5*	—	—	—	—	0·7*

* Nominal Composition.

Table II
Thermal-Expansion Coefficients of High-Temperature Alloys

	Average Coefficient × 10^{-6} inch/inch/°F.									
	70° to 600°	70° to 800°	70° to 1000°	70° to 1200°	70° to 1400°	70° to 1600°	70° to 1800°	70° to 2000°	70° to 2200°	70° to 2400°
HU	−7·4	7·5	8·1	8·4	8·8	9·3	9·4	9·8	10·0	—
Inconel X	7·6	7·8	8·1	8·5	9·0	9·7	10·3	10·6	10·8	11·3
HW	7·3	8·1	8·6	9·2	9·7	10·2	10·7	11·2	11·6	—
Vitallium	8·1	8·7	9·3	9·6	10·2	10·6	11·0	11·2	11·6	12·1
19-9 DL	9·1	9·4	9·8	10·2	10·4	10·7	11·1	11·3	11·6	12·0
N-155	9·1	9·5	9·7	9·8	10·2	10·5	10·9	11·4	11·7	—
S-590	7·8	8·4	9·3	9·8	10·4	11·0	11·6	12·2	12·7	13·0
16-25-6	9·0	9·4	9·6	10·2	10·8	11·7	12·0	12·4	13·0	13·3*
E.M.E.	9·4	10·1	10·8	11·4	11·9	12·4	12·9	13·2	14·0	14·5

* Incipient melting occurred.

currents through the specimens, the rate of heating depending on the current used.

A number of typical high-temperature alloys were selected to test the adaptability of the equipment: compositions and some of the test results are shown in the tables above.

Measurements on molybdenum and tungsten are also reported, and as a further check on the reliability of the dilatometer and its adaptability to transformation studies, an investigation was made on a steel for which data were already established: carbon 0·10, manganese 3·52, nickel 2·34, molybdenum 0·52, chromium 0·17, silicon 0·19, vanadium 0·15, per cent. The transformation data showed close agreement between the critical points as determined with this apparatus and by standard dilatometric methods.

Oxidation Characteristics of Nickel-Iron Alloys

See abstract on p. 13.

Nickel-Ceramic High-Temperature Materials

L. D. HOWER, J. W. LONDEREE and H. F. G. UELTZ: 'High-Temperature Bodies Derived from Mixtures of MgO-TiN-NiO.' *Jnl. Amer. Ceramic Soc.*, 1951, vol. 34, Oct., pp. 309-13.

The authors report a fundamental investigation of the properties of mixtures of the above type, made with a view to developing improved ceramels. Preliminary consideration of the structure of magnesium oxide, titanium nitride, and titanium carbide, and results of wetting tests with iron, cobalt, nickel and chromium, led to selection, for full-scale tests, of the following mixture: magnesium oxide 50, titanium nitride 30, nickel oxide 20, per cent.

Methods of preparation of the test bars are described in detail, and results of density, transverse strength, thermal-shock and oxidation tests are recorded. In the oxidation tests materials containing the three constituents in various other ratios were included.

Welding of Inconel 'W' Sheet

A. J. ROSENBERG: 'Welding Inconel 'W' Sheet.' *Steel*, 1951, vol. 129, Nov. 5, pp. 99-102.

The present shortage of niobium renders the alloy Inconel 'W' attractive vis-à-vis Inconel 'X', since the former is niobium-free. A typical composition of Inconel 'W' is given as nickel 73·5, chromium 15·0, titanium 2·5, aluminium 0·90, carbon 0·04, iron 7·0, manganese 0·50, silicon 0·40, sulphur 0·007, copper 0·20, per cent.

Welding procedure is identical for both alloys: resistance, metal-arc and inert-arc methods can be successfully used. This article gives some results of tests conducted to determine the ability of welded joints in Inconel 'W' to meet the stringent requirements laid down by the U.S. Air Force specifications. The text is illustrated by photographs of a number of welds made under various conditions, and by graphs demonstrating the properties obtainable in correctly produced welds. Some of the main points dealt with are summarized below:

Spot-Welding

Tests were made on unaged 1-in. × 4-in. coupons of 0·045-0·062- and 0·094-in. Inconel 'W', using conventional press-type equipment rated at 200 and 750 kva. Minimum and average strength requirements are shown in Table I below.

Table I

Material thickness ..	0·045 in.	0·062 in.	0·094 in.
Required average tensile shear force ..	2420 (1725)*	4010 (2740)*	7200 (4960)*
Minimum acceptable tensile shear force ..	2050 (1460)*	3400 (2320)*	6100 (4200)*
Average spot size (80% of sizes shown is an acceptable minimum)	·220	·250	·310

* Tensile shear forces for unaged material

It was found that excellent tensile-shear test results could be obtained at several conventional weld settings, using normal electrode forces, but under these conditions the material has a tendency towards weld porosity or dendritic shrinkage. Slow cooling of the weld, and/or use of high unit pressures obviates the defect. Table II shows the settings for three thicknesses tested, which conditions were found to produce welds giving test values above the requirements shown in Table I. In the case of short-time tensile-shear it was observed that annealing prior to age-hardening had no effect: welds tested in four conditions of heat-treatment failed at closely similar strength values. High-temperature stress-rupture results (for which no standards had previously been set up) indicated that there is a distinct advantage in annealing before ageing: at the 100-hour point such treatment yielded a 50 per cent. increase in strength.

Table II

Material thickness ..	0·045 in.	0·062 in.	0·094 in.
Machine force ..	2500 lb.	3400 lb.	4500 lb.
Time setting in cycles (on-off-pulsations)	20–5–10	20–10–10	20–15–10
Approximate current	8,700	10,500	12,000
Electrode	RWMA Class III, 3-in. radius		

Seam-Welding

As in spot-welding, Inconel 'W' shows a tendency to internal defects when seam-welded. Since seam-welding wheels are cooled by a stream of water directed at them and at the work, it is impossible to effect improvement by slowing the rate of cooling, but increase in electrode force was found to have a markedly beneficial effect. The equipment available to the author was limited to a force of 2700 lbs., but by changing the normal 3-in. radius faced wheels to 1½-in. radius faced wheels unit pressures were increased, and sound, ductile welds were produced.

Inert-Arc Welding

No difficulty was encountered in achieving sound, ductile welds by this process, using direct current, argon gas and metal backing. Direct ageing after welding gave welds comparable in strength to the basis metal, but for production of best properties in stress-rupture tests at elevated temperatures a direct ageing treatment after welding is desirable. Best results are obtained by using filler material of Inconel 'W' or 'X'.

Metal-Arc Welding

Results are shown for metal-arc welds on 0·045 in. and 0·062 in. Inconel 'W' sheet, using direct current and metal backing. Three electrodes were used: Inconel 132, and two experimental types, Inconel 132 R-42 and Inconel 'X' 139. Short-time tensile data on the welds indicate that the Inconel 'X' electrode is to be preferred where high strength in the weld is of importance. Welds made with all three electrodes were satisfactorily ductile. Stress-rupture values following a direct age-hardening treatment were the same for welds made with all three electrodes. Conclusions drawn with regard to annealing prior to age-hardening in inert-arc welding apply in this case also.

Slag removal is a problem in this process, and the author is of the opinion that hand-benching will be necessary. In addition, the high electrical resistivity of the Inconel 'X' 139 electrode causes the wire to overheat when welding at normal currents. Short lengths of electrode and minimum currents should therefore be employed.

Accelerated Oxidation in Molybdenum- and Vanadium-containing Materials

A. DE S. BRASUNAS and N. J. GRANT: 'Accelerated Oxidation of Metals at High Temperatures.' *Amer. Soc. Metals, Preprint* 3*W*, Jan.-Feb., 1952; 30 pp.

Following an introductory survey of major literature on accelerated oxidation occurring in molybdenum- or vanadium-containing materials at temperatures above 1500°F. (815°C.), the authors describe oxidation tests made on steels and alloys of the 16-25-6 types shown in Table I on p. 21, at various temperatures, and for various periods.

An illustrated description is given of test equipment

Chemical Composition of Alloys Studied

Designation	C %	Cr %	Ni %	Mo %	Si %	Mn %	V %
Molybdenum-bearing Alloys							
T-1	0·07	15·20	24·72	6·24	0·58	1·78	0·0
T-2	0·10	16·18	24·99	5·90	0·71	1·70	0·0
T-3	0·06	17·29	24·56	6·00	0·60	1·88	0·0
T-5	0·08	16·14	24·92	6·03	0·65	1·20	0·0
N.M. Series	0·1	var. *	25·0	6·0	0·2	0·7	0·0
C.M. Series	0·1	16·0	var. †	6·0	0·2	0·7	0·0
A Series		(Standard composition with miscellaneous variations)					
Vanadium-bearing Alloys							
T-6	0·29	17·48	24·28	0·0	0·52	0·2	4·59
N.V. Series	0·1	var. *	24·0	0·0	0·2	0·7	6·0
C.V. Series	0·1	16·0	var. †	0·0	0·2	0·7	6·0

* Chromium was varied from 0 to 35%. † Nickel was varied from 0 to 40%

and technique. The data recorded, correlated with observations which have been recorded earlier, are considered to have established the following facts concerning the phenomenon of accelerated oxidation in the 16-25-6 and related types of alloy:—

'Rate of oxidation increases as a function of time of exposure at temperature: at first it rises sharply with increase in temperature, until a point is reached beyond which further rise of temperature causes only slight additional oxidation. The rate of reaction is frequently so rapid that the liberated heat of reaction raises the temperature of the specimen, with consequent further acceleration of oxidation.

'Modifications in composition of the 16-25-6 type of alloy have in general only a slightly inhibiting influence on the excessive oxidation, but the presence of over 30 per cent. of nickel was found to confer satisfactorily oxidation-resistant properties, an effect which is explained as due to the relatively high stability of the complex nickel-rich oxide which forms on the higher-nickel alloys.

'Accelerated oxidation of commercial heat-resisting steels may be caused by direct or indirect contamination of the metal surfaces with low-melting or volatile metal oxides. Since the presence of contaminating oxides at the metal surface is critical, atmospheric circulation is essential only when dealing with readily volatile metal substances.

'The oxidation reaction occurs at the metal-oxide interface, and in the oxide at the interface abnormally large amounts of molybdenum and vanadium have been detected. The presence of this high concentration is believed to be essential to production of the high rate of oxidation, since artificial contamination with these oxides has been shown to induce attack on normally oxidation-resistant steels. Metal may be rapidly oxidized by molten MoO_3 or V_2O_5, and less rapidly by the corresponding vapours. The oxide formed at the interface is porous, permitting direct access of oxygen to the metal-oxide interface: it has a spinel-type structure.

'The thermal stability of certain vanadates and molybdates was determined and a correlation was found between these data and the effects produced by alloying additions made to vanadium- and molybdenum-containing alloys.'

It is suggested that the mechanism of accelerated (or 'catastrophic') oxidation is a reaction between molybdenum trioxide or vanadium pentoxide and unoxidized metal at the metal-oxide interface. Atmospheric oxygen penetrates the porous oxide and re-oxidizes the molybdenum and vanadium suboxides to their highest oxidation states. These mobile oxides then migrate to the metal surface as vapours or liquids, to attack the metal again.

Cerium and Lanthanum Additions to Promote Ductility in High-Alloy Steels

C. B. POST, D. G. SCHOFFSTALL and H. O. BEAVER: 'Hot-Workability of Stainless Steel Improved by Adding Cerium and Lanthanum.' *Jnl. of Metals*, 1951, vol. 3, Nov., pp. 973-77B.

This paper gives a full account of the developments at Carpenter Steel Company, briefly referred to in *Steel*, 1951, vol. 128, June 4, p. 98 (*Nickel Bulletin*, 1951, vol. 24, No. 8, p. 181), and covered by U.S. Patent 2,553,330 (*Nickel Bulletin*, 1951, vol. 24, No. 10, p. 222).

The investigations described have included the study of means for improving the ductility of stainless steels already possessing some degree of hot-workability, and the development of hot-workability in high-alloy materials previously considered to be non-hot-workable.

The report (presented at the Electric Furnace Steel Conference of the American Institute of Mining and Metallurgical Engineers in December, 1951) opens with a review of the variables known to affect hot-workability: stiffness, ingot structure, heating conditions used for hot-working operations, hot-shortness. The last-named factor is believed to overshadow all the others in its effect on hot-workability: its nature and significance are discussed at some length.

The next section of the report discusses the requirements of a test to determine forgeability, and describes the cone-test method which has been evolved at the Carpenter laboratory for evaluation of hot-ductility. The set-up is illustrated, and typical results obtained by it, on various materials, are shown. The conical sample, heated to the hot-working temperature, is placed on the die of the hammer and a light tap is given, to seat it firmly on to the base. A full blow of the 1½-ton hammer follows, driving the truncated portion down into the base, and spreading it. Examination of the periphery of the cone permits estimation of the hot-working properties of the material under test. Experience with this test has shown that if the ductility of the material is satisfactory by this standard, it will behave well in either hot-rolling or forging operations.

A detailed account is then given of experiments made on the addition of various amounts of rare-earth metals to austenitic steels and high-alloy materials of several types. Typical cone-test and related hot-workability data are presented for (1) an austenitic valve steel containing chromium 21, nickel 11, tungsten 3, nitrogen 0·20, per cent.; (2) a sulphuric-acid-resisting steel containing chromium 19·5, nickel 23, molybdenum 3·5, copper 1·5, manganese 2, silicon 1, per cent.; (3) a higher-alloy grade of sulphuric-acid-resisting steel containing chromium 20, nickel 28, molybdenum 2·5, copper 3·5, manganese 1, silicon 1, per cent.

A report is also made of experiments carried out to study the critical relationships between nickel and cerium + lanthanum contents required to secure optimum hot-workability. The scope of the research on this aspect of the subject is indicated by the range of composition of the materials used: see table below.

The effect of nickel content on maximum and minimum amounts of cerium and lanthanum required to improve hot-workability in alloys containing chromium, nickel and molybdenum is shown in the form of a chart. The range covered by the patent extends from 0·02 to 1·10 per cent. cerium and/or lanthanum with 4 per cent. nickel, to 0·02 to 0·15 per cent. with 70 per cent. nickel. It is pointed out by the authors of the present paper, however, that the critical rare-earth contents which produce optimum results may be much narrower than that indicated by the nickel content, such modification being dependent primarily on the presence of other alloy elements, such as molybdenum, copper, tungsten, etc.

The exact mechanism of the effect exerted by the Mischmetall (cerium, lanthanum, etc.) addition has not yet been determined. It is believed that some of the benefits obtained are certainly due to deoxidation, which is accompanied by a marked increase in the fluidity of the molten metal.

The major proportion of the results reported by the authors relate to the effects of Mischmetall in steels melted in high-frequency Ajax furnaces, but it has been found that the general conclusions drawn from the experimental work done with steels and alloys so produced can be applied to materials melted in the basic-electric-arc furnace, with only some modification in the optimum rare-earth content. Typical examples of such application are given, by means of data on Type 316, 316X, 310 and 308 stainless steels. In these steels cerium-lanthanum additions in the range of about 0·02-0·04 per cent. are effective in promoting hot-workability. In alloys such as Carpenter No. 20 (nickel-chromium-copper-molybdenum steel) and other highly alloyed stainless steels the preferred range of addition is 0·08-0·18 per cent.

Transformations in Precipitation-Hardening Nickel-Chromium Stainless Steel

W. H. COLNER and O. ZMESKAL: 'An Electrical Resistance Apparatus for Studying Transformations in Metals: Its Application to Transformations in Stainless Steel.' *Amer. Soc. Metals, Preprint* 5*W*, Jan.-Feb., 1952; 11 pp.

The authors describe electrical-resistance apparatus developed for use in heating and cooling studies and for isothermal investigations. The equipment is not of a highly specialized type, and is susceptible to easy modification to adapt it to most of the requirements of transformation studies. Design and operation are illustrated and the preparation and assembly of the specimen are described.

The specimen, in the form of wire, is heated and cooled in a furnace, or heated by an A.C. current, and is cooled by helium to the temperature of the furnace. Resistance is continuously recorded.

The equipment was used for the study of transformations occurring in a precipitation-hardening

C %	Mn %	Si %	P %	S %	Cr %	Ni %	Mo %
0·048	1·14	0·96	0·004	0·010	10·04	67·58	19·20
0·056	1·09	0·95	0·013	0·013	10·12	59·13	16·01
0·059	0·97	0·96	0·004	0·007	19·43	49·64	4·20
0·050	0·91	0·81	0·006	0·008	9·90	30·28	8·04
0·062	0·89	0·79	0·012	0·016	10·35	9·96	7·74

17-7 chromium-nickel steel (Type A.I.S.I. 322-W, Stainless 'W'): observations made on this steel are reported.

In this steel it was found that the precipitation and the ferrite-austenite reactions were associated with a decrease in electrical resistance. The effect, on the austenite-ferrite transformation, of solution temperature, rate of cooling, and interrupted cooling were studied. Progress of transformation at room temperature was followed for austenites of varying stability. A mechanism is proposed to account for observations made with regard to the influence of solution temperature.

Tantalum as Partial Replacement for Niobium in Stabilization of Stainless Steels

'Columbium and Tantalum in Austenitic Stainless Steels.' *A.S.T.M. Bulletin*, 1951, No. 177, Oct., pp. 17-19.

The A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys has recently given detailed consideration to the modification of specifications for austenitic steels, to permit, as far as possible, the conservation of niobium used as a stabilizer. The following recommendation, made as a result of authoritative data available to the Committee, is applicable to all austenitic stainless steels stabilized by niobium, in all forms covered by the specifications over which the Committee has jurisdiction, whether these deal with sheet, plate, bar, forgings, castings, pipe, or other forms. For the 'super-alloy' types of material no satisfactory substitute for niobium has been found.

'*Recommendation*

'In view of the limited availability of columbium (with the heretofore usual small percentage of tantalum) the stabilizing addition to Type . . . shall consist of columbium plus tantalum. The ratio of columbium to tantalum (in relation to the carbon content of the steel) and the maximum of each element, or of one of them, or of the two combined, shall be determined in accordance with the requirements of the end use and shall be as mutually agreed upon by producer and purchaser.'

It is pointed out that there is not yet sufficient detailed knowledge of the properties of the steels over the full range of such an addition, from almost total niobium on the one hand to almost total tantalum on the other, but that there is already some indication that two types of addition may emerge (especially in respect to the niobium-tantalum ratio), one being principally for use in materials for high-temperature applications, and the other better adapted for materials in which resistance to certain types of chemical attack is essential.

The Committee's announcement and recommendation are supported by an appendix entitled 'Columbium-Tantalum Alloys and their Use in Type 347,' by H. A. GROVE, which presents a detailed summary of test data showing that substitution of the currently available 40-20 niobium-tantalum ferro-alloy for the standard ferro-niobium formerly used is practicable. The results recorded have been taken from experimental and production heats made by steelmakers and producers of ferro-alloys: they include tests on bar, cast, sheet and strip material.

Mechanical tests, made at room and at elevated temperatures, demonstrate that no significant change results from the use of various ratios of niobium to tantalum within the limits studied. Tests of susceptibility to intergranular corrosion (made by both the Strauss and the Huey methods) proved that tantalum is as effective as niobium as a stabilizer.

Passivation of Stainless Steels

W. G. RENSHAW and J. A. FERREE: 'Passivating Characteristics of the Stainless Steels.' *Corrosion*, 1951, vol. 7, Oct., pp. 353-60.

The inherent ability of stainless steels to passivate in air or under other oxidizing conditions has for many years been accepted as a fact, but close investigation has indicated that the rate of growth of the films formed, and the degree of passivity attained, vary considerably according to the conditions obtaining and the state of the steels.

Solution-potential measurements have been used in various researches as a means of following the progress of film formation, and in this paper the authors describe the behaviour of stainless steels (410, 430, 446, 304, 310 and 316 types) in various solutions and in air, after a chemical activation treatment. The results show that when 30 per cent. nitric-acid solution is used as the cleaning agent it will also accelerate the rate of passivation, as compared with that found in air, but that the state eventually reached is about the same in the two cases. Ground or sandblasted surfaces are found to passivate as readily as other surfaces (and in some cases more readily).

Although the authors do not consider that specific laws of passivation can be derived from the data presented, they interpret the results as indicating that the passivation of mechanically activated surfaces is similar to low-temperature oxidation. There are also indications that the passive effect produced in orthophosphoric acid or sodium hydroxide may be due to formation of a protective film of corrosion product on the surface, rather than to the passive film which, according to the usual concept, is caused by an oxidizing environment.

Testing of Stainless Steel for Susceptibility to Intergranular Corrosion

A. FERRI: 'Investigations on Stainless Steels.' *Metallurgia Italiana*, 1951, vol. 43, Oct., pp. 432-4.

Comparison was made of the Strauss (acidified-copper-sulphate) and Huey (boiling-nitric-acid) tests, on three types of austenitic steel (straight 18-8, 18-8-Mo and 18-8-Ti), all of which had been subjected to sensitizing treatments. The results lead the author to the conclusion that the Strauss test is the more sensitive of the two. Scatter of test results is discussed in relation to factors influencing intercrystalline corrosion, e.g., grain size, amount of carbide precipitation, surface condition of the steels, etc.

Table I

Loss in Weight of Stainless-Steel Strips in Dilute Acids at 25°C.

Exposure	1 Day			5 Days			10 Days			2 Weeks			6 Weeks			10 Weeks		
Acid dilution	0·01 *N*	0·1 *N*	1 *N*	0·01 *N*	0·1 *N*	1 *N*	0·01 *N*	0·1 *N*	1 *N*	0·01 *N*	0·1 *N*	1 *N*	0·01 *N*	0·1 *N*	1 *N*	0·01 *N*	0·1 *N*	1 *N*
Acid	Weight Loss, Mg. per 100 sq. cm. of Surface Exposed																	
Boric*	2·4	1·4	1·8	1·8	0·8	1·0	1·8	0·8	0·8	2·0	0·8	1·2	2·0	1·4	1·0	2·0	1·4	1·4
Hydrobromic	2·0	2·8	24·1	1·8	2·4	24·9	1·6	2·0	24·3	1·4	2·2	25·3	1·2	2·2	25·9	1·6	2·8	27·9
Hydrochloric	2·0	1·6	84·4	1·0	1·0	196·2	1·0	0·6	277·0	1·0	1·4	325·1	1·0	2·0	698·7	2·0	2·0	894·5
Hydriodic	1·8	2·4	1·8	0·8	1·4	1·6	1·4	1·0	1·0	1·0	1·8	2·0	1·0	1·8	2·0	1·8	1·8	2·0
Nitric	2·6	1·6	1·2	1·6	1·0	1·0	1·0	0·8	1·7	1·8	1·4	1·6	1·6	1·2	1·7	2·4	1·6	1·9
Phosphoric	1·4	1·6	1·0	1·2	1·0	1·0	1·4	1·2	1·4	1·4	2·0	1·4	1·2	2·2	1·4	2·0	2·2	1·6
Phosphorous	1·8	1·6	2·1	1·6	1·0	1·6	1·0	1·0	2·0	1·6	1·6	2·3	1·2	1·0	2·0	2·6	1·2	2·3
Sulphuric	1·8	2·1	2·4	1·6	1·0	1·6	1·6	1·6	1·4	1·8	1·6	1·4	1·8	2·0	1·4	2·4	2·2	2·4
Sulphurous	2·4	1·4	1·4	1·0	0·8	1·8	1·6	1·2	1·2	1·4	0·8	0·8	1·8	1·6	1·8	1·8	1·6	2·5
Selenious	2·0	1·6	1·4	1·6	0·8	0·8	0·8	0·4	0·6	1·0	0·8	1·4	1·4	1·0	1·4	1·6	1·6	1·8

*Boric acid was a saturated solution or 0·715 *N*.

Table II

Loss in Weight of Stainless-Steel Strips in Dilute Acids Boiled 30 minutes daily

Exposure	1 Day			3 Days			5 Days			10 Days			2 Weeks			6 Weeks			10 Weeks		
Acid dilution	0·01 *N*	0·1 *N*	1 *N*	0·01 *N*	0·1 *N*	1 *N*	0·01 *N*	0·1 *N*	1 *N*	0·01 *N*	0·1 *N*	1 *N*	0·01 *N*	0·1 *N*	1 *N*	0·01 *N*	0·1 *N*	1 *N*	0·01 *N*	0·1 *N*	1 *N*
Acid	Weight Loss, Mg. per 100 sq. cm. of Surface Exposed																				
Boric*	0·2	0·6	0·0	0·6	0·6	0·4	0·5	0·6	1·0	0·5	1·0	0·4	0·8	1·0	0·8	0·6	1·8	0·8	1·6	2·4	1·4
Hydrobromic	1·4	0·8	83·5	1·4	1·4	249·4	1·2	1·4	421·4	1·2	1·8	730·8	1·4	1·8	988·2	1·1	1·8	2414·0	2·4	2·8	3188·4
Hydrochloric	1·2	20·6	360·8	1·0	71·7	805·7	1·4	107·6	1078·8	1·4	189·5	1506·0	1·0	267·5	1791·8	1·2	274·2	4455·7	2·2	279·2	5768·3
Hydriodic	0·4	0·6	23·7	1·6	0·2	56·1	1·2	0·6	78·6	1·2	0·8	140·7	2·0	1·5	231·3	1·6	1·0	608·3	2·4	2·6	665·6
Nitric	1·0	1·0	5·4	1·6	0·6	5·4	0·8	1·0	6·2	0·8	1·0	6·4	1·2	1·2	6·5	1·3	1·2	6·5	2·0	2·2	6·9
Phosphoric	1·2	1·0	+0·2	1·4	0·8	0·6	1·0	1·0	1·0	1·0	1·4	0·6	1·2	1·0	1·0	1·0	1·0	0·6	2·2	2·2	2·0
Phosphorous	0·2	0·6	+0·2	1·0	1·4	0·2	1·2	1·4	1·0	1·2	2·0	0·2	1·6	1·8	0·6	1·2	1·6	1·0	2·2	2·3	1·6
Sulphuric	1·2	19·6	153·1	1·6	19·4	153·7	1·4	19·4	155·0	1·4	19·8	154·2	1·6	20·0	154·6	2·0	20·0	154·6	2·6	21·8	155·5
Sulphurous	0·8	1·0	64·1	1·4	61·2	64·6	1·0	61·2	65·0	1·0	61·8	69·1	1·2	62·4	67·0	1·0	61·2	67·6	2·0	62·4	68·0
Selenious	0·6	1·2	0·2	1·2	0·6	0·4	1·2	0·8	1·5	1·2	1·4	0·8	1·3	1·0	1·2	1·4	1·0	2·3	2·3	1·8	2·9

* Boric acid was a saturated solution or 0·715 *N*

Resistance of Stainless Steels to Dilute Inorganic Acids

C. F. POE and R. M. MALCOM: 'Action of Dilute Inorganic Acids on Stainless Steel.' *Industrial and Engineering Chemistry*, 1951, vol. 43, Nov., pp. 2572-5.

The paper reports a series of tests on 18-8 chromium-nickel steel of the following composition: carbon 0·087, silicon 0·38, manganese 0·45, sulphur 0·009, phosphorus 0·021, nickel 9·11, chromium 18·33, iron 71·55, per cent. The sheet used was tested in the fully-annealed condition, the samples being exposed in the form of strip 'W' specimens, in order that the maximum possible surface should be presented to the liquid and a minimum surface should be in contact with the bottom of the container flask. The solutions were un-aerated.

The samples were kept in contact with the solutions at 25°C. for 10 weeks, being removed, washed, dried and weighed at intervals of 1, 3, 5, 7 and 10 days, and 2, 4, 6, 8 and 10 weeks. On another set of samples this procedure was repeated, except that instead of maintaining a constant temperature of 25°C., each acid, with the specimens in situ, was boiled for 30 minutes daily during the whole of the 10-week period. Reflux condensers were used to prevent evaporation. Blank determinations were made with distilled water in both series of tests.

Results of the tests are shown in Tables I and II on p. 24.

After the 2- and 10-week periods small amounts of acid solution were removed for determination of the iron, chromium and nickel contents. Table III shows results of the analyses for some of the more active acids.

The authors comment critically on the results. Data in Table I indicate the activity of hydrochloric acid, which caused a fairly regular loss of weight throughout the 10-week period. Boric, phosphoric and selenious acids caused the least loss in weight. Table II shows that the normal acids when boiled for 30 minutes daily caused considerable losses: hydrochloric acid was the most corrosive, followed by hydrobromic, hydriodic, sulphuric, and sulphurous acids. Of the 0·1-*N* solutions, hydrochloric, sulphurous and sulphuric acid caused the most severe loss.

Table III demonstrates the fact that the elements present in nickel-chromium stainless steel are not dissolved by the acids in the same proportions as those in which they are present in the steel: in every case the amount of nickel in the solution was less.

Correlation of Test Data with Service Performance

See abstract on p. 4.

Corrosion Research: Activities of U.S. and Canadian Organizations

'Technical Organizations Unite to Combat Corrosion.' *A.S.T.M. Bulletin*, 1951, No. 177, Oct., pp. 14-16.

A condensed and informative summary is made of the activities of the main organizations in North America engaged in corrosion research. The scope of work of the following societies is described: National Association of Corrosion Engineers, the Inter-Society Corrosion Committee (an organization integrating the work of technical societies and Government agencies engaged in corrosion research in North America), the American Electroplaters' Society, the American Society for Testing Materials, the Association of American Railroads, the Electrochemical Society, the Federation of Paint and Varnish Production Clubs, the National Bureau of Standards, the National Research Councils of U.S.A. and of Canada, and the Office of Naval Research.

Sub-Zero Impact Properties of Stainless Nickel-Chromium and High-Nickel Steels

T. N. ARMSTRONG and A. J. MILLER: 'Impact Properties of Stainless Steel and 9 per cent. Nickel Steel after Exposure under Stress to Liquid Nitrogen.' *A.S.T.M. Bulletin*, 1951, No. 177, Oct., pp. 35-6.

Earlier tests have shown that chromium-nickel stainless steels, 9 per cent. nickel steel and 3½ per cent. nickel steel suffer no deterioration in impact-resistance after immersion in liquid nitrogen for one year. This later report gives results of tests in which 9 per cent. nickel steel and 25-20 and 18-8-Mo chromium-nickel steels were exposed at −320°F. (−196°C.) *under stress*.

Specimens were prepared from both stainless steels in the annealed condition and from butt-welds made by the metal-arc process, using covered electrodes of the same types as the parent plates. The welded speci-

Table III

Iron, Chromium and Nickel Dissolved by Different Acids

Acid	Mg. per 100 Ml. Acid			Results on Percentage Basis		
	Fe	Cr	Ni	Fe	Cr	Ni
Hydrobromic	435·3	136·1	19·1	74	23	3
Hydrochloric	945·8	211·2	37·2	79	18	3
Hydriodic	106·7	41·7	5·7	69	27	4
Sulphuric	22·9	11·0	3·2	62	29	9
Sulphurous	16·6	4·2	1·4	75	19	6

Table I
Charpy Impact (ft.-lb.) of Stainless Steels at −320°F. (−196°C.) Keyhole Notch

Type Stainless Steel	PLATE		WELD	
	Unstressed	Stressed 30,000 p.s.i. (13·4 t.s.i.) 13 days	Unstressed	Stressed 30,000 p.s.i. (13·4 t.s.i.) 13 days
310	49, 50, 48	50, 50, 45	22, 26, 27	26, 27, 28, 32
316	64, 65, 26	58, 62	18, 16, 18	22, 21, 24

Table II
Charpy Impact (ft.-lb.) of 9 per cent. Nickel Steel at −320°F. (−196°C.) Keyhole Notch

	Unstressed	Stressed 30,000 p.s.i. (13·4 t.s.i.)		
		2 days	2 weeks	2 months
Plate	25, 26, 30	24, 28, 29, 37	18, 20, 23, 28	24, 28, 29
Weld Interface ..	20, 26, 26	20, 24, 25, 26	17, 21, 24, 25	23, 26, 26, 26

mens of these steels were tested in the as-welded condition. The 9 per cent. nickel steel was double-normalized and re-heated to 1050°F. (565°C.). Butt welds in this steel were made with Type 310 electrodes and the welded specimens were re-heated to 1050°F. (565°C.) and cooled in air after welding. A tensile stress of 30,000 p.s.i. (13·4 tons per sq. in.) was applied, in a specially designed test assembly which is illustrated in the note, and were then immersed in liquid nitrogen. The stainless-steel specimens were kept in these conditions for two weeks prior to impact test: nickel-steel specimens were tested after exposures of 2 days, 2 weeks and 2 months.

The tests on the chromium-nickel steels were not continued longer, since it is believed that if no alteration occurs in a few days at a low temperature it is unlikely that a longer period will cause change. Absence of any deterioration in the 9 per cent. nickel steel is confirmed by results obtained by l'Air Liquide, Montreal, showing that six months' exposure caused no fall in impact. These latter tests are being continued to a year's duration. The stainless steels were notched in the unaffected base metal and in the weld metal: welded specimens were not stress-relieved. The impact specimens of the welded nickel steel were prepared in such a way that the bottom of the notch was at the interface of the parent metal and the weld metal.

Test results, see tables above, show that the values for any one material fall within a scatter band which appears to be unaffected by the duration of exposure under stress at the sub-zero temperature. The one low value recorded for Type 316 steel was from an unstressed specimen, and is believed to represent an abnormality. Tests at room temperature were made only for check purposes, since the impact properties of all three steels have already been adequately reported in the literature, to which references are given.

Wear and Friction Properties of High-Nickel Alloys

See abstract on p. 10.

Machining of Stainless Steel: Defense Production Aid Service

J. DE FEHER: 'Machining of Stainless Steel.' *U.S. Dept. of Commerce, Business Information Service, Defense Production Aids*, No. 9, Mar., 1951; 4 pp.

The U.S. Department of Commerce is issuing to industry a series of leaflets giving information on problems which may arise in connexion with production of items under the defence programme. They are directed in particular to those who may be working on materials with the properties of which they may not be familiar; the notes are therefore relatively elementary, but practically useful.

In No. 9 the characteristics of the chromium and nickel-chromium stainless steels are briefly reviewed, and recommended procedure for machining is concisely summarized under the following headings: machining characteristics, turning tools, drilling, reaming, tapping, threading, milling, boring, cutting fluids, drawing, spinning, polishing (grinding, polishing and buffing, electrolytic polishing,), riveting, blanking and punching, shearing.

Gas-Cutting of Stainless Steels

A. B. KINZEL: 'Powder Cutting Handles Stainless with Ease.' *Steel*, 1951, vol. 129, Nov. 5, pp. 94-6.

The article is based on a paper presented to the International Institute of Welding at their Oxford Conference, 1951. It describes the method of gas cutting developed by Union Carbide and Carbon Corporation, in which iron powder is introduced into the gas stream, permitting rapid oxidation of the stainless steel. The apparatus consists of a cutting

blowpipe, with supply of oxygen and fuel gas, and a powder-dispensing device. With the exception of the powder dispenser, all the equipment is of standard commercial design, and the powder dispenser has been designed to permit of addition to standard cutting and scarfing torches. Pneumatic and vibrating dispensers are available; the applications of the two types are described.

A section of the paper contains practical recommendations on powder-cutting procedure, covering choice of equipment, positioning of torch, gas supply, flow of powder, and other details. With regard to the effects of powder/gas cutting of the stainless steels, it is stated that if the steel would be suitable for service in the as-welded condition it will be equally serviceable in the powder-cut condition. If, however, heat-treatment would be required after welding, annealing after powder cutting may be advisable: alternatively, stabilized steels may be used.

The authors state that powder cutting has also achieved considerable success in the non-ferrous industries. In some cases 10-30 per cent. aluminium is added to the iron powder when cutting non-ferrous materials, to produce a more reactive mixture. The method has been successfully applied to copper, nickel, brass, bronze, magnesium, aluminium, the Hastelloy alloys, Inconel, and Monel, as well as to some refractory (ceramic) materials. A further use of the powder method is to give a quick start in the cutting of carbon steel: once cutting is well started the flow of powder may be stopped.

Conditioning of stainless-steel ingots, blooms, billets and slabs is an important application of the powder-cutting process: scarfing by this method is claimed to have effected economy and introduced a higher standard of product in continuous-production shops. Powder flow can be regulated according to the surface finish required on the work: high powder-flow rates give smooth surfaces suitable for final rolling to sheet, while lower rates of flow are adequate for rough conditioning during the breakdown stages of the hot-working.

Fabrication and Welding Procedure for Nickel-Chromium Stainless Steels

P. L. POCOCK: 'The Fabrication and Welding of Austenitic Stainless Steels.' *Sheet Metal Industries*, 1951, vol. 28, Oct., pp. 933-42, 944.

A well-illustrated article dealing with equipment and technique required for successful processing of nickel-chromium stainless steels. Introductory notes on composition, prevention of weld decay and general precautions desirable in handling this type of material are followed by discussion of procedure for shearing, cutting and machining; cutting (by the powder-cutting and the oxy-arc methods), and welding (carbon-arc, gas, argon-arc and metallic-arc processes).

An account is given of investigations made by the author to elucidate the causes of unsatisfactory welds in stainless steel and to develop optimum procedure for welding by the metallic-arc process. Among the points to which particular attention is directed are the importance of using dried and undamaged electrodes, the avoidance of excessive welding currents, and the advantages of multi-run technique in producing welds with refined structure. Recommended preparatory and welding techniques are concisely summarized in tabular form.

Welding of Nickel and Nickel Alloys

See abstract on p. 11.

Inert-Arc Welding of Nickel and Stainless-Steel Tubing

See abstract on p. 7.

Nickel-Chromium Stainless Steels in Transport Equipment

P. ECHALIER: 'Stainless Steel in Surface Transport.' *Rev. du Nickel*, 1951, vol. 17, Oct.-Dec., pp. 79-84.

Introductory note on the properties of 18-8 steels which render them suitable for constructional purposes, and on the economy obtainable due to the high strength/weight ratio of the high-tensile types of these steels, followed by review of uses of stainless steels in railway stock, Diesel railcars, freight trailer vehicles and other transport applications.

Stainless-Steel Railway Coaches

'Stainless Steel Coaches.' *Railway Gazette*, 1951, vol. 95, Nov. 30, p. 596.

The General Roca Railway has placed in service twelve stainless-steel air-conditioned coaches built by the Budd Company of U.S.A. They will be used, in two express trains of six coaches each, on the route between Buenos Aires and Mar del Plata: the journey will be made at an average speed of 80 kilometres per hour (approx. 50 miles per hour). The coaches are 26 metres long and weigh 55 tons.

Stainless-Steel Parachute Springs

'Stainless Adopted for Parachute Springs.' *Nickel Topics*, 1951, vol. 4, No. 8, p. 8.

Rubber, which has for some years been the standard material for parachute springs, has been found to deteriorate under the wide range of temperature and humidity conditions to which such equipment is subject. In view of the supreme importance of this application, the U.S. Government has permitted the use of nickel-chromium stainless steel, and all U.S. parachutes are now being equipped with springs of that material. The wire used has a tensile strength of the order of 300,000-350,000 p.s.i. (134-156 tons per sq. in.) which is maintained up to about 500°F. (260°C.), and has a further attribute which is even more important in this application, freedom from embrittlement at temperatures below zero, thus ensuring retention of the required properties under high-altitude conditions. An additional point in favour of stainless steel for parachute springs is the fact that storage or non-use for long periods, which would almost inevitably mean deterioration of other spring materials, will leave the stainless-steel springs in perfect condition, ready to function efficiently whenever required.

Hard-Facing Materials: Properties and Uses

H. S. AVERY: 'Hard Facing Alloys for Steel Mill Use.' *Iron and Steel Engineer*, 1951, vol. 28, Sept., pp. 81-106.

This paper is a critical analysis of the properties of hard-facing materials currently used, with some suggestions of suitable uses for the respective types. It is emphasized that although it is possible to group such materials according to composition, it is a dangerous fallacy to assume that alloy content, regardless of structure, is a reliable criterion of abrasion- and wear-resisting qualities or of some of the other characteristics required in hard-facing alloys.

The classification worked out on the basis of composition by the American Welding Society is reproduced, supplemented by a table in which the various types are graded according to properties, see below. The major part of the review comprises evaluation of the respective materials in the order of that grading.

Structures typical of alloys of the various groups are illustrated, with notes on their effect on the durability, wear-resistance, abrasion-resistance (wet- and dry-sand erosion factors), hot-hardness, creep-resistance, high-temperature mechanical properties, and other qualities which influence the behaviour of hard facings produced from the respective materials.

A Graded Series of Wear Resistant Alloys

Increasing abrasion resistance ↑	1. Tungsten-carbide composites	Maximum abrasion-resistance Worn surfaces become rough
	2. High-chromium irons	Excellent erosion-resistance Oxidation-resistance
	3. Martensitic irons	Excellent abrasion-resistance High compressive strength
	4. Cobalt-base alloys	Oxidation-resistance Corrosion-resistance Hot-strength and creep-resistance
	5. Nickel-base alloys	Corrosion-resistance May have oxidation- and creep-resistance
Increasing toughness ↓	6. Martensitic steels	Good combinations of abrasion- and impact-resistance Good compressive strength
	7. Pearlitic steels	Inexpensive. Fair abrasion- and impact-resistance
	8. Austenitic steels Stainless steels Manganese steel	Work-hardening Corrosion-resistance Maximum toughness with fair abrasion-resistance. Good metal to metal-wear; resistance under impact

Properties sensitive to carbon content and structure

The classification given in the table omits reference to copper-base alloys, but the author points out that the aluminium-bronze group have properties which merit attention in this connexion.

The paper contains much well-illustrated and correlated data, culled from many sources. In discussion, it was stated that the American Welding Society and the American Society for Testing Materials are currently preparing tentative specifications for five types of hard-facing material already in large-scale commercial use.

Monel in Tannery Equipment

G. W. DOUGLAS: 'Tannery Maintenance: Corrosion-Resistance of Pipes, etc.' *Jnl. Soc. Leather Trades' Chemists*, 1951, vol. 35, Oct., p. 350 (from *Australian Leather Trade Rev.*, 1951, vol. 47, p. 5).

'The acidity and alkalinity of processing liquors requires the use of special alloys. An aluminium alloy (to D.T.D. 346) is specially suitable for toggles: cases have been known of staining by Staybrite in drying plants. Polymer linings may be applied to wood, steel or concrete pits. The principles of painting steelwork are considered, also the precautions to be taken in their application. Points from the discussion were:— Staybrite steel was not so resistant to corrosion as Monel in vegetable tan liquors . . . Monel had resisted for three years solutions containing up to 7 per cent. NaCl + 3 per cent acid . . .'

PATENTS

Cathode Starting Sheets for Electrolytic Refining of Nickel

A cathode starting sheet for use in electro-refining of metals has the greater part of its area plane and the remainder deformed into stiffening ribs separate from one another and of substantially greater width than depth. The method is particularly described with reference to refining of nickel, but is also applicable in the extraction of copper and lead.

MOND NICKEL CO., LTD. *Brit. Pat.* 658,150.

Machinable Graphitic Nickel and Nickel-Tin-Silicon Alloys

A graphitic nickel casting alloy having high strength, wear-resistance, ductility and machinability, and characterized by a structure containing nodular graphite, is of the following composition: carbon 0·8-3, silicon 1-4, manganese 0·5-4, sulphur up to 0·08, magnesium exceeding the sulphur by 0·035-0·45 per cent., balance nickel.

G. L. LEE and J. T. EASH, assignors to INTERNATIONAL NICKEL CO., INC. *U.S. Pat.* 2,568,013.

A related patent covers graphitic nickel-alloy castings having the same type of structure and properties, but of the following composition: carbon 0·8-2·5, tin 1-6, silicon 0·5-4, manganese 0·5-4, sulphur in amount not subversive to formation of nodular

graphite, magnesium exceeding the sulphur by 0·03-0·25 per cent., iron up to 10, per cent., balance nickel. Preferred melting and casting procedure is described in both patents.

J. T. EASH and G. L. LEE, assignors to INTERNATIONAL NICKEL CO., INC. *U.S. Pat.* 2,568,014. (Similar to *Brit. Pat.* 660,063.)

Nickel or Nickel-Alloy Coating for Prevention of Oxidation during Hot Working

Metal articles (in particular blades for gas-turbine compressors) made from ferrous metal blanks by hot-working are coated (by plating or spraying) with nickel, chromium, or a nickel-chromium alloy before heating. Decarburization and formation of scale is thus avoided without the need for using a non-oxidizing atmosphere.

ROLLS ROYCE, LTD., AND G. ECCLES. *Brit. Pat.* 659,573.

Fluxes for Welding of Nickel Alloys

In gas-welding alloys of high nickel content the flux is a mixture consisting (by weight) of barium fluoride 40-70, calcium fluoride 10-40, barium chloride 10-20, sodium fluoride 0-15, per cent., with 2-10 per cent. of a water-dispersible organic binder.

MOND NICKEL CO., LTD. *Brit. Pat.* 662,493.

Bright-Nickel Plating of Electropolished Surfaces

Treatment of an electropolished surface of brass comprises rinsing, immersion in a 10 per cent. sulphuric-acid solution containing 0·5-10 oz. per gallon of oxalic acid, a second rinsing and finally bright-nickel plating.

C. L. FAUST and J. G. BEACH, assignors to BATTELLE DEVELOPMENT CORPN. *U.S. Pat.* 2,563,229.

Electrodeposition of Nickel with Insoluble Anodes: Replenishment of Nickel-Plating Baths

MOND NICKEL CO., LTD. *Brit. Pat.* 659,335. (Corresponding to *U.S. Pat.* 2,541,721, see abstract in *Nickel Bulletin*, 1951, vol. 24, No. 10, p. 219.)

Production of Nickel Sulphate from Scrap Nickel Anodes

Nickel or nickel scrap anodes are dissolved electrolytically at 50°-80°C. in a sulphuric-acid bath maintained at 1-4*N*. Lead or molybdenum insoluble cathodes are used and the current density at the cathode is kept at 2-10 times that operative at the anode.

STÉ. D'ÉLECTRO-CHIMIE, D'ÉLECTRO-MÉTALLURGIE ET DES ACIÉRIES ÉLECTRIQUES D'UGINE. *French Pat.* 983,071.

Electrodeposition of Nickel-Tin Alloys

Tin-nickel alloy coatings containing 50-90 per cent. tin are electrodeposited from an aqueous solution containing tin: nickel from 2 : 1 to 1 : 7. Bath contains tin, nickel and alkali metal cations, and as anions chlorides alone, chlorides+fluorides, chlorides+sulphates and fluorides, or fluorides alone. The compositions of preferred baths are given. (Cf. papers on this development abstracted in *Nickel Bulletin*, 1951, vol. 24, No. 5, p. 101.)

J. IRELAND, N. PARKINSON and TIN RESEARCH INST. *Brit. Pat.* 661,154.

Re-Plating of Articles after Stripping

A nickel-plated article from which chromium has been anodically stripped in a caustic-alkali solution is (1) made cathode in a strong hydrochloric solution for about one minute, using current density of 75-100 amp./sq. ft., (2) flash-coated with copper, and (3) nickel plated.

C. F. WEBER, assignor to GENERAL ELECTRIC COMPANY. *U.S. Pat* 2,570,174.

Mercury Coating of Nickel

A nickel surface is etched with nitric acid and then wetted in a bath containing acetic acid, hydrochloric acid, or sulphuric acid resting on a layer of mercury, and immediately lowered into the mercury. Material so treated gives improved behaviour in mercury switches of both instant- and delayed-action types.

T. M. BURKHOLDER, assignor to RAYTHEON MANUFACTURING CO. *U.S. Pat.* 2,567,762.

Precipitation-Hardenable Nickel-Copper-Manganese Alloys

The compositions of nickel-copper-manganese alloys having a wide range of mechanical and physical properties, combined with a good degree of corrosion-resistance, are defined graphically by reference to the ternary diagram. Typical compositions for which properties are cited include alloys containing nickel from 10 to 25 per cent., with varying proportions of copper and manganese.

CHICAGO DEVELOPMENT CO. *Brit. Pat.* 658,264.

Mechanical, Magnetic and Thermal Treatments of High-Permeability Nickel-Iron Alloys

Magnetic and electrical characteristics of ferro-magnetic alloys (especially the 50/50 nickel-iron type) are improved by orienting the grain by severe cold reduction (at least 99 per cent.), followed by annealing in magnetic field applied in a preferred direction. The alloys are preferably cast in partial vacuum, to give very low oxygen and carbon contents. They are annealed in pure hydrogen, hot-rolled, cold-rolled, re-heated in hydrogen at 1000° to 1150°C. for 2 hours, rapidly cooled, re-heated in hydrogen to 500°C., and slowly cooled to 100°C. over a period of 18 hours, under the influence of a strong magnetic field.

E. A. GAUGLER. *U.S. Pat.* 2,569,468.

Powder Loading Coils of High-Permeability Nickel-Cobalt-Iron Alloy

Recrystallized mixed sulphates of ferromagnetic metals are converted to mixed oxides by rapid heating, and the oxides are reduced by heating in a reducing gas, to give a friable alloy. The powder obtained from this alloy has high initial permeability, with low coercive force and residual induction; it is suitable for cores of loading coils, inductances and the like. An

example cites a powder alloy containing nickel 45, iron 31, cobalt 24, per cent.

COMMUNICATION ENGINEERING PTY., LTD. *Brit. Pat.* 658,241.

Nickel-containing Permanent-Magnet Alloys

The patent specifies treatment producing magnetic anisotropy in an alloy or sintered mass containing nickel 10-30, aluminium 6-11, cobalt 12-30, copper 0·5-8, niobium 1·5, tantalum 1·5, per cent., balance iron. The material is subjected to the action of a magnetic field while cooling through the Curie point from the solution temperature, and is subsequently aged.

WM. JESSOP AND SONS, LTD. *Brit. Pat.* 659,527.

Sintered metal mixtures for anisotropic magnets contain iron, nickel, aluminium, at least 14 per cent. cobalt, and optionally up to 10 per cent. of other elements. A preferred composition is given as cobalt 14-30, nickel 7-30, aluminium 5-11, copper 0-10, titanium 0-5, silicon 0-5, zirconium 0-5, per cent., balance iron. A pressed body of the powdered material is sintered in a non-oxidizing atmosphere whilst protected from direct access of the atmosphere by a porous mass containing (1) a powdered or granulated alloy of titanium and/or other element or elements having a high affinity for carbon and nitrogen, and (2) aluminium and/or other metal or metals which are readily oxidizable at high temperatures. The protective alloy may be mixed with an inert refractory, e.g., Al_2O_3, and/or the refractory may be interposed between the powder to be sintered and the protective mass.

MUREX, LTD. and G. L. MILLER. *Brit. Pat.* 659,998 (Patent of addition to 571,317).

An iron-aluminium-nickel-cobalt alloy, preferably containing cobalt 15-40, nickel 10-28, aluminium 6-11, copper 0-7, titanium 0-7, per cent., balance iron, with optionally up to 1 per cent. each of tungsten, chromium, molybdenum, vanadium, zirconium, calcium, cerium, silicon, is cast in such a way as to have a chiefly (100) orientation, and the magnetizing fields are applied parallel to the (100) direction. When chill casting is used to orient the crystals the titanium content should not exceed 0·7 per cent. $BH_{max.}$ values up to 8×10^6 are claimed for magnets so produced.

PHILIPS ELECTRICAL, LTD. and W. T. DEAN. *Brit. Pat.* 660,580.

A further patent covers controlled cooling, ageing and magnetic treatment of iron-base alloys containing aluminium 6-11, nickel 10-20, cobalt 16-30, niobium 0·5-10, copper up to 7, titanium up to 5, per cent., with or without up to 1 per cent. total and not more than 0·5 per cent. of any one of the following elements: tungsten, chromium, molybdenum, vanadium, zirconium, calcium, cerium, tantalum and silicon, balance iron. An alloy containing aluminium 8, nickel 13, cobalt 25, copper 3, niobium 2·5, per cent., cast to give columnar crystals, magnetized in the (100) direction, and suitably heat-treated, is claimed to show a $BH_{max.}$ of $6\text{-}7\times10^6$, and coercive force above 750 oersted.

PHILIPS ELECTRICAL, LTD., W. T. DEAN and J. V. HARDING. *Brit. Pat.* 660, 591.

A related patent covers similar treatment for alloys containing aluminium 6-11, nickel 10-20, cobalt 16-30, niobium 0-10, tantalum 0·5-12, copper 0-7, titanium 0-5, per cent., with or without up to 1 per cent. total and not more than 0·5 per cent. of any one of the following elements: tungsten, chromium, molybdenum, vanadium, zirconium, calcium, cerium and silicon, balance iron. A preferred composition is given as aluminium 8, nickel 13, cobalt 25, copper 3·5, tantalum 5, per cent., balance iron, which, when cast to give columnar crystals and magnetized in the (100) direction, is claimed to give a $BH_{max.}$ of $6\text{-}7\times10^6$ and coercive force of more than 850 oersted.

PHILIPS ELECTRICAL, LTD., W. T. DEAN and J. V. HARDING. *Brit. Pat.* 660, 592.

Permanent magnets (e.g., of the Alnico type) showing columnar crystallization are made by casting alloys in baked hollow-core sand moulds with chills at one or both ends. The moulds may be made of sand containing chemically exothermic material (e.g., a mixture of aluminium powder with sodium carbonate and iron oxide). Moulds and chills may be embedded in green sand.

SWIFT LEVICK AND SONS, LTD., G. D. L. HORSBURGH and F. W. TETLEY. *Brit. Pat.* 661,727.

Nickel-Iron Hairspring Alloys

A compensating hairspring showing elasticity at least equal to that of tempered steel hairsprings is made of an α-iron-nickel alloy of the following composition: nickel 24-27, carbon 0·20-0·7, niobium 1-5, manganese 0·5-1·0 per cent., balance iron. Aluminium may be present up to a quarter of the amount of the niobium, provided that the niobium+aluminium content equals 0·1 to 5 per cent.

E. DUBOIS. *U.S. Pat.* 2,568,326.

Treatment of Nickel-Iron-base Alloys having Low Coefficient of Elasticity

The range of temperature over which the coefficient of elasticity remains small in nickel-iron alloys is widened and controlled by a balanced relation of composition, degree of cold-work and heat-treatment. Treatment comprises cold-working followed by annealing at a temperature above 150°C. and below the temperature of full recrystallization. The composition of the alloys is defined by reference to a given region in the ternary iron-nickel-molybdenum diagram. Preferred alloys and treatments are given as:

(1) nickel 42·7, manganese 0·66, per cent., remainder iron; reduced 78 per cent., annealed at 400°C.
(2) nickel 42·1, molybdenum 5·1, manganese 0·37, per cent., remainder iron; reduced 56 per cent., annealed at 400°C.
(3) nickel 40·1, molybdenum 10·8, manganese 0·17, per cent., remainder iron; reduced 5 per cent., annealed at 400°C.

(4) nickel 38·4, molybdenum 10·7, manganese 0·13, per cent., remainder iron; reduced 41-67 per cent., and annealed at 400°C.

The invention is claimed to be specially applicable to vibrating-reed selector switches, but is also useful for any device containing an element which functions by elastic distortion.

M. E. FINE, assignor to BELL TELEPHONE LABORATORIES, INC. *U.S. Pat.* 2,561,732.

Nickel-containing Sealing Alloys

An iron-nickel-copper alloy for use in sealing contains iron 54 max., copper at least 1 (preferably 1-7), nickel preferably 48-56, per cent. Nickel is in specified relation to the copper content. Such alloys are suitable for sealing to glass having a coefficient of expansion greater than 80×10^{-7}.

N.V. PHILIPS GLOEILAMPENFABRIEKEN. *Belgian Pat.* 502,357.

The expansion curve of the alloy containing iron 54, nickel 28, cobalt 18, per cent. closely matches that of borosilicate glass of the following composition: SiO 64·90, B_2O_3 22·50, iron oxide 0·08, Al_2O_3 4·90, Na_2O 7·00, Ce oxide 0·50, Sb_2O_3 0·11, per cent. Good seals can be made.

H. R. BLACK, assignor to OWENS-ILLINOIS GLASS CO. *U.S. Pat.* 2,564,950.

Magnesium Treatment of White Cast Irons

Improved strength and other properties are obtained in unalloyed or nickel-containing white cast irons by treatment with magnesium, in amount calculated to give a residual magnesium content of 0·015-0·5 per cent. Special reference is made to cast irons of the following range of composition: total carbon 2·5-3·3, silicon 0·3-1·25, nickel 3·5-5, manganese 0·4-0·9, magnesium 0·05-0·1, per cent. The microstructure of these cast irons is unusual, being characterized by the presence of carbides in the form of laminations or plates and by the fact that the carbide phase is discontinuous. Such irons show good resistance to wear and abrasion and are very hard: they are suitable for use in lining plates or balls for grinding mills, and for rolls.

MOND NICKEL CO., LTD. *Brit. Pat.* 657,870.

Nickel-Chromium-Manganese Steels for Tyres, etc.

Steels of the following composition are claimed to be specially suitable for tyres for railway and tramway wheels, rails, pressings, rivets, sheets, etc.: carbon 0·14-0·26, silicon 0·50-1·50, manganese 0·80-1·50, nickel 0·80-1·80, chromium 0·50-1·50, per cent. with or without small amounts of molybdenum and/or vanadium and/or copper.

TERNI (SIA. PER L'INDUSTRIA E L'ELETTRICITA), V. DE GASPARI, and A. BARTOCCI. *French Pat.* 984,180.

Vacuum Melting of Complex Nickel-containing High-Temperature Alloys

Alloys of high purity containing at least three of the elements iron, chromium, nickel and cobalt with small amounts of titanium, zirconium and carbon, are produced by vacuum melting followed by chill casting.

J. D. NISBET, assignor to GENERAL ELECTRIC CO. *U.S. Pat.* 2,564,498.

Boron Additions to High-Temperature Steels

Boron additions (0·005-0·1 per cent.) are used to improve the high-temperature strength of austenitic steel containing chromium 10-30, carbon up to 0·5, iron at least 50, per cent., a sufficient amount of nickel and/or manganese to make the steel completely austenitic, and preferably also molybdenum up to 7·5, tungsten up to 15, per cent., and from 2 to 5 per cent. of at least one of the elements niobium, tantalum, vanadium and titanium. The steel is hot-worked and then reduced by 10-40 per cent. at temperatures between 1000°F. (538°C.) and the recrystallization temperature, with or without intermediate solution heat-treatment.

W. O. BINDER, assignor to UNION CARBIDE AND CARBON CORPN. *U.S. Pat.* 2,562,854.

Precipitation-Hardened Complex Austenitic Steels for High-Temperature Service

The range of composition covered is carbon not less than 0·15, silicon up to 2, manganese up to 2, nickel 25-40, chromium 20·1 to 25, cobalt 18-30, titanium up to 5, and either tungsten 2-6 or molybdenum 1-6, per cent., or both tungsten and molybdenum in a combined total of 2-10, per cent., balance iron. Such steels are precipitation-hardened by cooling from 800°-1300°C., followed by one or more re-heatings to 400°-900°C. for 2-300 hours. The re-heatings are arranged to precipitate successively different hardening elements. The steels may also contain boron up to 0·2, and/or aluminium up to 4, per cent.

STÉ. ANON. COMMENTRY-FOURCHAMBAULT ET DECAZEVILLE. *Brit. Pat.* 657,818.

Creep-Resisting Nickel-Chromium-Tungsten Steels

Austenitic steels characterized by good strength at high temperatures and particularly good creep-resistance are made by cold-working steels of the following composition: carbon 0·05-0·15, chromium 16-18, nickel 11-14, silicon 0·1-1, manganese 0·2-1, tungsten 2·5-4·5, titanium 0·4-0·8, per cent. Working is continued to a stage at which the proof stress corresponding to a permanent elongation of 0·2 per cent. becomes equal to, or greater than, 45 kg./mm. The resistance to flow increases with rise in tungsten content.

STÉ. D'ÉLECTRO-CHIMIE, D'ÉLECTRO-MÉTALLURGIE ET DES ACIÉRIES ÉLÉCTRIQUES D'UGINE.

Non-Magnetic High-Strength Complex Nickel Alloy Steels

Steels covered contain nickel 19-25, manganese 2-6, chromium 5-14, aluminium 3-5, silicon up to 3 per cent., other elements which do not impair the age-hardening and non-magnetic properties in a total of not more than 3 per cent., balance iron. Solution treatment at 2100°-2300°F. (1150°-1260°C.), followed

by ageing at 1200°-1300°F. (650°-705°C.) gives a hardness above 35 Rockwell C, and a 0·02 per cent. yield strength of 85,000 p.s.i. (38 tons per sq. in.).
P. PAYSON, assignor to CRUCIBLE STEEL CO. OF AMERICA. *U.S. Pat.* 2,561,945.

Nickel-Chromium and Nickel-Chromium-Manganese Steels Resistant to Attack by Leaded Fuels

Steels claimed to show good high-temperature strength and resistance to corrosion by gases arising from combustion of lead-containing fuels are of the following composition: chromium 12-30, nickel 2-35, and/or manganese up to 17 per cent. (provided that the nickel+manganese content is not more than 47 per cent.), carbon 0·05-1·5, silicon 0·45 max., sulphur 0·5 max., nitrogen 0·3 max., per cent., balance iron. The steel may contain up to 30 per cent. cobalt, or up to 4·5 per cent. molybdenum.
ALLOY RESEARCH CORPN. *French Pat.* 984,192.

Steels claimed to have good resistance to corrosion in the presence of the combustion products of leaded fuels are of the following approximate composition: carbon 0·10-1·25, chromium 12-25, nickel 4-35, per cent., at least 0·15 but not more than 0·5 per cent. sulphur, remainder substantially iron.
ARMCO STEEL CO. and W. C. CLARKE. *U.S. Pat.* 2,557,862.

Dental Alloy

An alloy for dentures contains carbon 0·05 max., manganese 0·60 max., silicon 0·60 max., nickel 55-62, chromium 14-17, copper 13-20, molybdenum 3-4, aluminium 0·02-0·10, titanium 0·40-0·60, zirconium 0·40-0·60, silver 0·60-0·80, per cent.
S. LOW. *U.S. Pat.* 2,570,355.

Sub-Zero Processing of Austenitic Nickel-Chromium Steels

Fully austenitic nickel-chromium steels are locally formed (e.g., sheets dimpled or tubes flared) after cold-working, without danger of consequent cracking, by carrying out such local deformation at a temperature below −18°C., preferably at −45°C. to −100°C. The method has particular application to steels containing nickel 8-12, chromium 17-19, carbon 0·03-0·12, manganese 0·5-1·5, silicon 0·3-1, niobium 0-1·5, titanium 0-1, zirconium 0-0·6, selenium 0-0·5, copper 0-1, molybdenum 0-0·6, per cent., balance iron, with usual impurities.
MOND NICKEL CO., LTD. *Brit. Pat.* 662,522.

A related patent claims that the employment of the sub-zero temperature of working reduces the amount of cold work required to raise the room-temperature hardness and strength of an austenitic nickel-chromium steel to a pre-determined extent, and also claims that the ductility is not so severely reduced by working at the sub-zero temperature.
MOND NICKEL CO., LTD. *Brit. Pat.* 662,523.

Nickel-Chromium-Iron Welding Electrode and Flux

In a.c. or d.c. arc-welding improved welds are obtained with an electrode consisting of a core containing nickel 80, chromium 14, iron 6, per cent. with a flux comprising a mixture of $CaCO_3$ up to 30, BaF_2 9-25, Na_3AlF_6 10-50, ferro-niobium up to 32, ferro-titanium up to 12, bentonite 2-5, dextrine 1-5 parts, by weight. Preferred compositions for the flux are given.
T. E. KIHLGREN and J. S. BRYNER, assignors to INTERNATIONAL NICKEL CO., INC. *U.S. Pat.* 2,576,123.

Extra-Low-Carbon Welding Rods

Weld rods giving extra-low-carbon stainless-steel deposits consist of a core of stainless steel containing chromium 10-35, carbon not more than 0·03, per cent. (preferably chromium about 21, nickel about 10, manganese about 1·5, per cent., balance iron), and a coating containing niobium oxide, less than 0·03 per cent. carbon, low-carbon ferro-aluminium or ferro-silicon as reducing agent, a flux (e.g., CaO-CaF_2) and a binder.
A. L. FEILD, assignor to ARMCO STEEL CORPN. *U.S. Pat.* 2,564,474.

Brazing of Oxidation-Resistant Materials

Chromium-containing materials of which the surface-oxide film can be reduced on heating in an atmosphere having a relative water-vapour pressure above about 10^{-5} (particularly stainless steels) are brazed in a reducing atmosphere, with a nickel-copper-chromium-silicon alloy containing preferably less than 75 per cent. copper, with silicon up to 3, chromium 10-25, per cent., and, optionally, manganese, titanium, and/or niobium. In an example two types of stainless steel of different compositions are joined with a brazing alloy containing nickel 50, copper 40, chromium 10, silicon 1, niobium 0·1, manganese 0·25, per cent., by heating for 2 minutes under hydrogen at 1280°C.
N.V. PHILIPS GLOEILAMPENFABRIEKEN. *Brit. Pat.* 657,123.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks.*

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